INSTRUCTION MANUAL

TYPE 541A OSCILLOSCOPE

Tektronix, Inc.
S.W. Millikan Way ● P. O. Box 500 ● Beaverton, Oregon ● Phone MI 4-0161 ● Cables: Tektronix

Tektronix International A.G.
Terrassenweg 1A ● Zug, Switzerland ● PH. 042-49192 ● Cable: Tekintag, Zug Switzerland ● Telex 53.574

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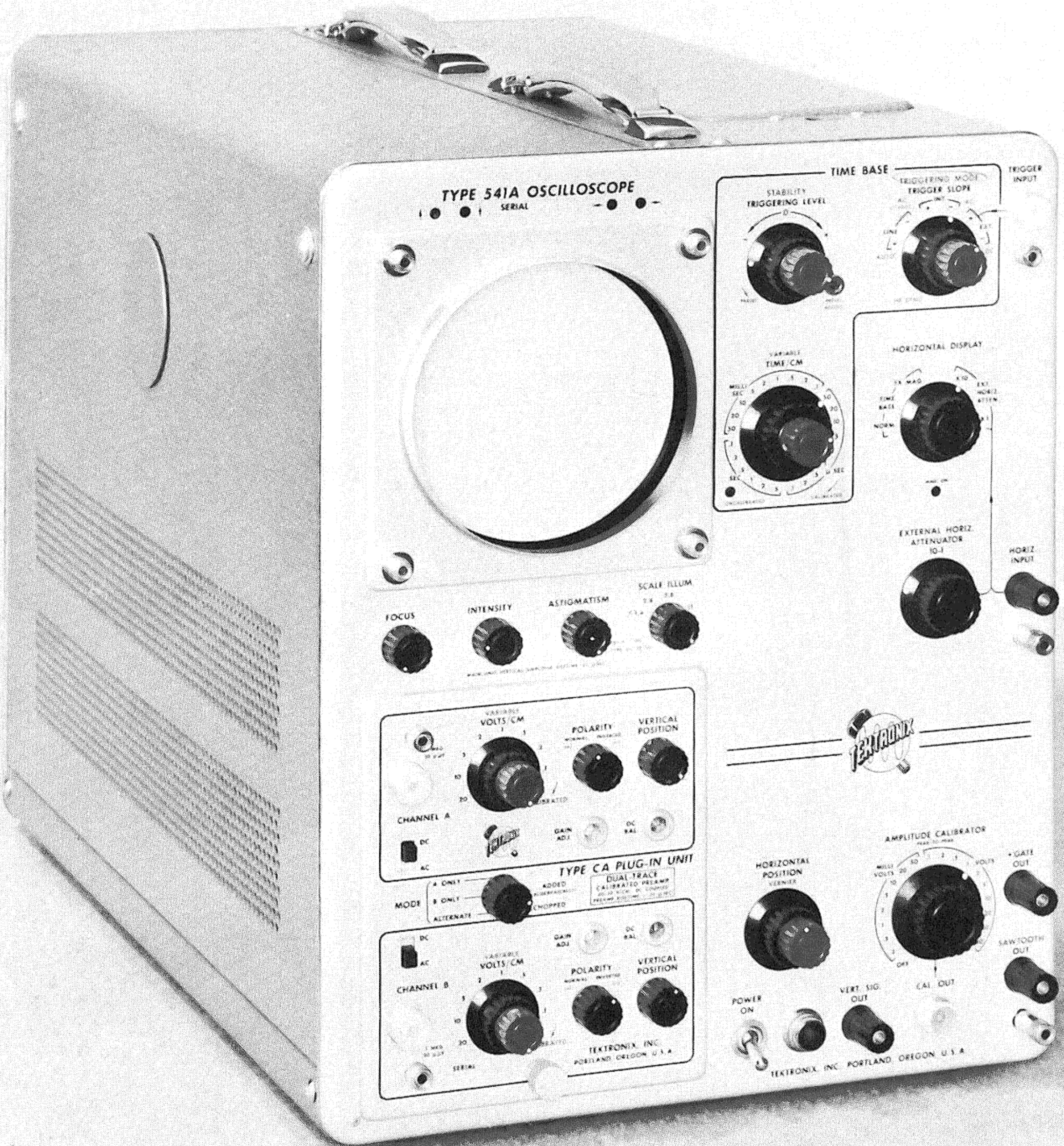
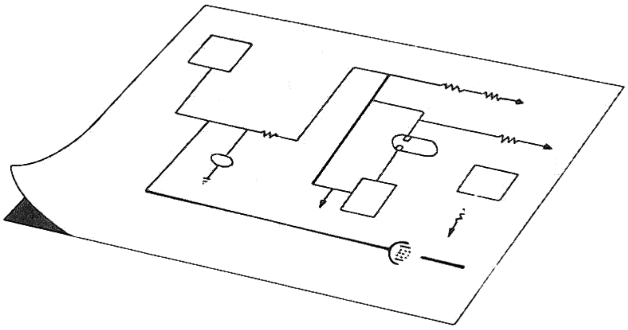

TYPE 541A OSCILLOSCOPE
SERIAL
TIME BASE
TRIGGER INPUT
STABILITY
TRIGGERING LEVEL
TRIGGERING MODE
TRIGGER SLOPE
VARIABLE
TIME/CM
HORIZONTAL DISPLAY
EXTERNAL HORIZ. ATTENUATOR
10-1
HORIZ. INPUT
FOCUS
INTENSITY
ASTIGMATISM
SCALE ILLUM
VOLTS/CM
POLARITY
VERTICAL POSITION
CHANNEL A
GAIN ADJ
DC BAL
DC
AC
TYPE CA PLUG-IN UNIT
DUAL-TRACE
MODE
A ONLY
B ONLY
ALTERNATE
ADDED
CHOPPED
CHANNEL B
TEKTRONIX, INC.
PORTLAND, OREGON, U.S.A.
TEKTRONIX
HORIZONTAL POSITION
AMPLITUDE CALIBRATOR
+GATE OUT
SAWTOOTH OUT
POWER ON
VERT. SIG. OUT
CAL. OUT
TEKTRONIX, INC. PORTLAND, OREGON, U.S.A.

SECTION 1



CHARACTERISTICS

General

The Tektronix Type 541A Oscilloscope is a general purpose instrument well suited to laboratory use. Plug-in preamplifiers are used in the vertical-deflection system, permitting the instruments to be used in many specialized applications, including, among others, wide band, dual trace, low level, differential, maximum frequency response and risetime, and transistor risetime checking.

Vertical Deflection System

All specifications for the Vertical Deflection System of the Type 541A Oscilloscope depend upon the plug-in unit used with the instrument. The following specifications are given assuming that a Type K Plug-In Unit is used.

Bandpass—DC to 30 mc (down 3 db ± ½ db at 30 mc)

Risetime—.012 microseconds.

Delay Line—Balance Network Signal Delay—0.2 μsec.

Horizontal Deflection System

Triggering Modes—Automatic, AC Low Frequency Reject, AC, DC and High Frequency Sync.

Triggering Signal Requirements

Internal—a signal producing 2 mm of vertical deflection

External—a signal .2 volts to 10 volts, peak to peak. (The sweep will trigger on larger signals, but the TRIGGERING LEVEL control operates over a ± 10 volt range.)

Triggering Frequency Range—triggered operation to 5 mc.

Synchronizing Signal Requirements

Internal—a signal producing 2 cm of vertical deflection

External—a signal of 2 volts

Synchronizing Frequency Range—synchronized operation 5 mc to 30 mc.

Sweep Rates

0.1 microseconds to 5 seconds per centimeter in 24 accurately calibrated steps. An uncalibrated control permits sweep speeds to be varied continuously between 0.1 microseconds and approximately 12 seconds per centimeter. Calibrated sweep speeds are typically within 1%, and in all cases within 3%, of the indicated sweep rate.

Magnifier

Provides a 5-times magnification of the center 2-centimeter portion of the oscilloscope display. Accuracy within 5% when the magnified sweep does not exceed the maximum calibrated rate of 0.02 microseconds/cm attained with the Magnifier ON.

Unblanking

DC Coupled

External Horizontal Signal Input

Deflection factor—approximately 0.2 to 15 volts per centimeter, continuously variable.

Frequency Range—dc to 240 kc in calibrated position. (3 db down at 240 kc.)

Input Impedance—approximately 47 μμf paralleled by 1 megohm.

OTHER CHARACTERISTICS

Cathode-Ray Tube

Type T543/P2—P1, P7 and P11 phosphors optional.

Accelerating potential—10,000 volts.

Vertical Deflection Factor—approx. 7 v/cm.

Horizontal Deflection Factor—approx. 30 v/cm.

Usable viewing area—4 by 10 centimeters

Amplitude Calibrator

Square-wave output at approximately 1 kc

Output Voltages—0.2 millivolts to 100 volts peak-to-peak in 18 calibrated steps.

Accuracy—peak-to-peak amplitude of square waves within 3% of indicated voltage

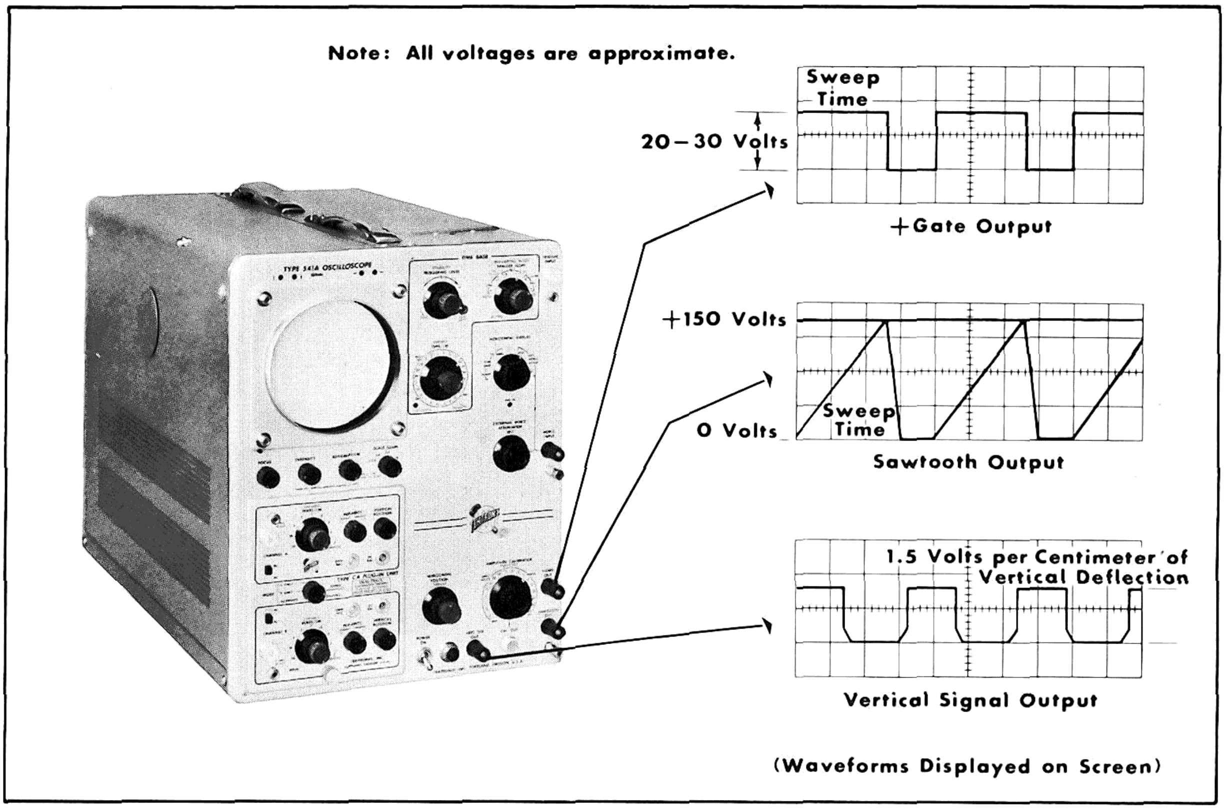


Fig. 1-1. Output waveforms available at the oscilloscope front panel.

Power Supplies

Electronically regulated for stable operation with widely varying line voltages and loads.

Line voltage requirements—105 v to 125 v, or 210 v to 250 v, 50 to 60 cycles.

Power—500 watts with Type CA Plug-In Unit.

Output Waveforms Available

+Gate Output—approximately 20 volts peak-to-peak with same duration as sweep.

Sawtooth Output—Sweep sawtooth waveform, approximately 150 volts maximum.

Vertical Signal Output—output from vertical deflection system, approximately 1.5 volts peak to peak per centimeter of vertical deflection.

Mechanical Characteristics

Ventilation—filtered, forced air. Thermal relay interrupts instrument power in the event of overheating.

Finish—photoetched, anodized panels. Blue finish, perforated cabinets.

Construction—aluminum alloy chassis and three-piece Cabinet

Dimensions—24" long, 13" wide, 16¾" high.

Weight—61½ pounds.

Accessories

2—Type P6000 Probes, 010-020
2—Type A510 Binding Post Adaptors, 013-004
1—Test Lead (012-031)
1—Green Graticule Filter, 378-514
2—Instruction Manuals
1—3 to 2-wire Adaptor, 103-013
1—3-conductor power cord, 161-010

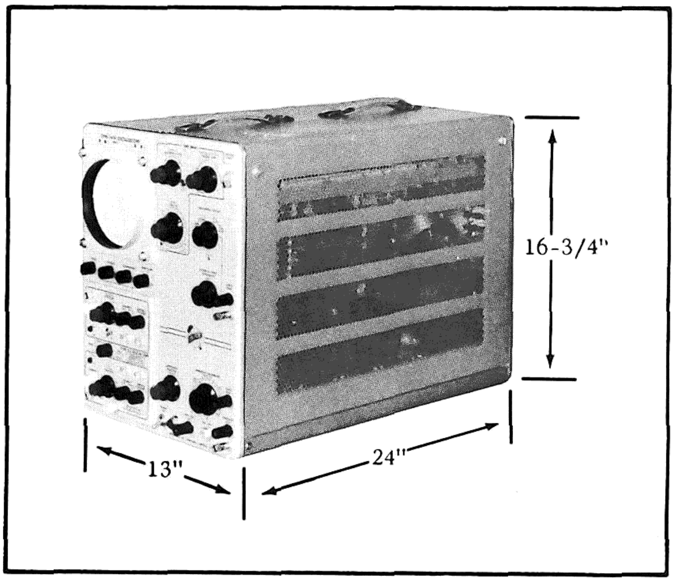


Fig. 1-2. Type 541A Oscilloscope Dimensions.

PLUG-IN PREAMPLIFIER CHARACTERISTICS FOR TYPE 541A OSCILLOSCOPE

PLUG-IN TYPE	CALIBRATED DEFLECTION FACTOR	PASSBAND	RISETIME	INPUT CAPACITANCE
TYPE A Wide-Band DC Coupled	0.05 v/cm to 20 v/cm	dc to 20 mc	18 nsec	47 pf
TYPE B Wide-Band	5 mv/cm to 0.05 v/cm	2 c to 12 mc	30 nsec	47 pf
High-Gain DC Coupled	0.05 v/cm to 20 v/cm	dc to 20 mc	18 nsec	
TYPE CA Dual-Trace DC Coupled	0.05 v/cm to 20 v/cm	dc to 24 mc	15 nsec	20 pf
TYPE D † High-Gain DC Coupled Differential	1 mv/cm to 50 v/cm	dc to 2 mc	0.18 μsec	47 pf
TYPE E Low-Level AC Coupled Differential	50 μv/cm to 20mv/cm	0.06 cycles to 60 kc	6 μsec	50 pf
TYPE G Wide-Band DC Coupled Differential	0.05 v/cm to 20 v/cm	dc to 20 mc	18 nsec	47 pf
TYPE H DC Coupled High-Gain Wide-Band	5 mv/cm to 20 v/cm	dc to 15 mc	23 nsec	47 pf
TYPE K Fast-Rise DC Coupled	0.05 v/cm to 20 v/cm	dc to 30 mc	12 nsec	20 pf
TYPE L Fast-Rise	5 mv/cm to 2 v/cm	3 c to 24 mc	15 nsec	20 pf
High-Gain DC Coupled	0.05 v/cm to 20 v/cm	dc to 30 mc	12 nsec	
TYPE N * Pulse Sampling	10 mv/cm	600 mc	0.6 nsec	Input Impedance, 50 ohms.
Type P is a fast-rise step-function test signal unit.				
TYPE Q * Strain Gage	10 μstrain/div to 10,000 μstrain/div	dc to 6 kc	60 μsec	Adjustable
TYPE R * Transistor Risetime	0.5 ma/cm to 100 ma/cm		12 nsec	
TYPE S * Semiconductor Diode Recovery	0.05 v/cm and 0.5 v/cm			
TYPE T * Time-Base Generator				
TYPE Z * DC Coupled Differential Comparator	0.05 v/cm to 25 v/cm	dc to 13 mc	27 nsec	24 pf

* More data available on the special-purpose plug-in units in the following paragraphs.

† At sensitivities greater than 0.05 v/cm, maximum bandpass is less than 2 mc. At 1 mv/cm, it is approximately 350 kc.

Type N

The Type N Sampling Unit is designed for use with Tektronix plug-in type Oscilloscopes. The sampling system thus formed permits the display of repetitive signals with fractional nanosecond (10^{-9} second or nsec) risetime. By taking successive samples at a slightly later time at each recurrence of the pulse under observation, the Type N reconstructs the pulse on a relatively long time-base. Specifications of the Type N include a risetime of 0.6 nsec, corresponding to a maximum bandpass of approximately 600 mc; a sensitivity of 10 mv/cm with 2 mv or less noise; and a dynamic range of ±120 mv minimum linear range before over-loading results.

Accidental overload of ±4 volts dc is permissible.

Type P

The Type P Plug-In Unit generates a fast-rise step-function test signal of known waveform, simulating the output of an ideally compensated Type K Unit driven with a Tektronix Type 107 Square-Wave Generator. The Type P permits the standardization of the main-unit vertical amplifier transient response of a Tektronix convertible oscilloscope. Risetime of the Type P is approximately 4 nanoseconds when it is used to standardize a Type 541-Series Oscilloscope. Pulse repetition rate is 240 step functions per second, with either positive or negative polarity. Step function amplitude is continuously adjustable between 0 and 3 major graticule divisions.

Type Q

The Type Q Plug-In Unit permits any Tektronix convertible oscilloscope such as the Type 541A to be operated with strain gages and other transducers. Excitation voltages for the strain gages and transducers are provided by the plug-in unit. The unit provides high gain, low noise, and extremely low drift. Frequency response of the Type Q Plug-In Unit is DC to 6 kc; risetime is approximately 60 microseconds. Strain sensitivity is calibrated in 10 steps from 10 microstrain per major graticule divisions to 10,000 microstrain per division, and is continuously variable between steps.

Type R

The Type R Plug-In Unit is a combined power supply and pulse generator which is used to measure the high frequency characteristics of junction transistors by the pulse-response method. When the Type R is used in an oscilloscope having a delay line, delay time, risetime, storage time, and falltime may be displayed simultaneously. A pushbutton switch connects a front-panel terminal directly to the input of the oscilloscope for observing externally derived waveforms.

Pulse risetime of the Type R Unit is less than 5 nanoseconds, so measurements depend on the risetime of the oscilloscope used. Pulse amplitudes are in 8 fixed, calibrated steps from .05 to 10 volts, adjustable between steps. Pulse recurrence frequency is 120 pulses per second.

Type S

The Type S Plug-In Unit is designed for use with Tektronix Wide-Band convertible oscilloscopes. Using the Type S, voltage across a test diode is displayed as a function of time.

Certain diode parameters, such as junction resistance, junction capacitance, and the stored charge at the junction, can be measured readily and reliably from the display. Performance of a diode in a particular circuit can be predicted by analyzing the recovery and "turn-on" characteristics. Since it is essentially a means for plotting voltage across an element while passing constant current through it, the unit can be used for other applications as well. For example: observing the junction characteristics of transistors, or measuring the resistance, capacitance or inductance of circuit components.

The Type S offers calibrated forward currents in five fixed steps from 1 to 20 milliamps, and reverse currents calibrated in six steps from 0 to 2 milliamps. Diode shunt capacitance is 9 picofarads, and deflection factors are 0.05 v/cm and 0.5 v/cm, calibrated.

Type T

The Type T Time-Base Generator provides sawtooth sweep voltages from 0.2 μsec/div to 2 sec/div. The trigger source may be line frequency, external, ac or dc coupled, automatic or high-frequency sync. The triggering point can be on either rising or falling slope of the waveform, and triggering level is adjustable. A signal of 0.2 to 50 volts is required for triggering.

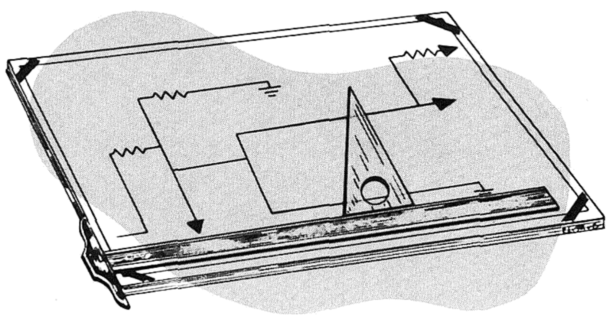
Type Z

The Type Z Plug-In Unit extends the accuracy of oscilloscope voltage measurements. It can be used in three modes of operation: (1) as a conventional preamplifier, (2) as a differential input preamplifier, or (3) as a calibrated differential comparator. With sensitivity of 50 mv/cm *and insertion* voltage range of ±100 volts, the effective scale range is ±2000 cm. Maximum resolution of the Type Z Unit is .005%.

As a conventional preamplifier, the Type Z offers a passband of dc to 13 mc for the 541A for signals that do not overscan the screen. The deflection factors are 0.05 volts/cm to 25 v/cm in 9 fixed, calibrated steps.

As a differential input preamplifier, the Type Z accepts a common-mode signal level ±100 volts with input attenuation X1, and offers a common-mode rejection ratio of 40,000 to 1. Maximum input signal is 1 volt/7 nsec, or —1 volt/5 nsec.

As a calibrated differential comparator, the Type Z makes available three comparison voltage ranges; from zero to ±1 volt, zero to ±10 volts, and zero to ±100 volts.



SECTION 4

CIRCUIT DESCRIPTION

VERTICAL DEFLECTION SYSTEM

General

The dc-coupled push-pull main Vertical Amplifier provides the necessary gain to drive the Delay Line and the vertical deflection plates of the crt. The main units of the Vertical Amplifier are the Input Amplifier stage V1014 and V1024, the Cathode-Follower Driver stages V1033 and V1043, and the 6-stage Distributed Amplifier output stage. Other circuits of importance are the Trigger Pickoff Amplifier V1054 and V1064, the Trigger Pickoff C.F. V1223B, the Vert. Sig. Out. C.F. V1223A and the Indicator Amplifiers and Lamps, V1084A and B1083, and V1084B and B1087, respectively.

Input Circuit

The signal input from the plug-in unit is coupled through terminals 1 and 3 of the interconnecting plug to the grids of the Input Amplifier stage. R1027 varies the cathode degeneration, and thus sets the gain of the stage to agree with the Preamplifier's front-panel calibrations when the VARIABLE knob is in the CALIBRATED position.

The Input Amplifier is coupled to the Distributed Amplifier by the cathode followers V1033 and V1043. The cathode followers isolate the Distributed Amplifiers from the Input Amplifier, and provide the necessary low-impedance drive for the Distributed Amplifier's grid line.

High-frequency compensation for the Input Amplifier is provided by the variable peaking coils L1014 and L1024. Variable inductors L1036 and L1046 provide additional peaking at the very high frequencies.

Output Stage

The output stage is a 6-section Distributed Amplifier. The tapped inductors in the transmission line, between each grid and between each plate, isolate each section from the capacitance of the adjacent sections.

The input signal for each tube is obtained from the grid line, which is driven by the cathode followers V1033 and V1043. The amplified signal at each plate, fed to the plate line, becomes an integral part of the wave traveling down the line toward the deflection plates.

The vertical signal is delayed 0.2 microsecond between the input to the grid line and the vertical deflection plates. This delay insures that the very "front" of fast vertical signals can be observed. About 0.015 microsecond of the total delay time occurs in the Distributed Amplifier; the remaining 0.185 microsecond occurs in the Delay Line.

The tapped inductors between each section of the Distributed Amplifier provide about 0.003 microsecond of delay. By making the delay time in the grid and plate lines equal, the signal arriving at each plate, through the electron stream of the tube, will be synchronous with the signal moving down the plate line from the preceding sections.

DC Shift Compensation

DC shift in the amplifier—a condition whereby the dc and very low-frequency transconductance is less than at mid-frequencies—is compensated for in two ways. R1090 and C1093B in plate line L1104, and R1095 and C1093D in plate line L1114, form a low-frequency boost network; the time constant of this network is such that the termination resistance of the line is increased in the range from very low frequencies to dc. A longer time constant, for extremely low-frequencies and dc compensation, is provided by R1092, R1094 and C1093A in one plate line, and by R1097, R1099 and C1093C in the other, which provide a small amount of positive feedback from the plate lines to the plate circuits of the Input Amplifier. A variable resistor R1091, the DC Shift control, is connected between the two networks to adjust for the proper amount of compensation.

Beam-Positioning Indicators

The beam-position indicators B1083 and B1087, located on the front panel above the crt, indicate the relative vertical position of the trace with respect to the center of the graticule. When the beam is centered vertically, the potential across either neon is insufficient to light it. As the beam is positioned up or down the screen, however, the current through the Indicator Amplifiers, and hence the voltage across the neons, will change. The voltage across one neon will increase, causing it to light, and the voltage across the other will decrease, causing it to remain extinguished. The neon that lights will indicate the direction in which the beam has been moved.

Trigger Pickoff

When internal triggering of the Time Base Generator is desired (black TRIGGER SLOPE knob in either the + or — INT. position), a "sample" of the vertical signal is used to

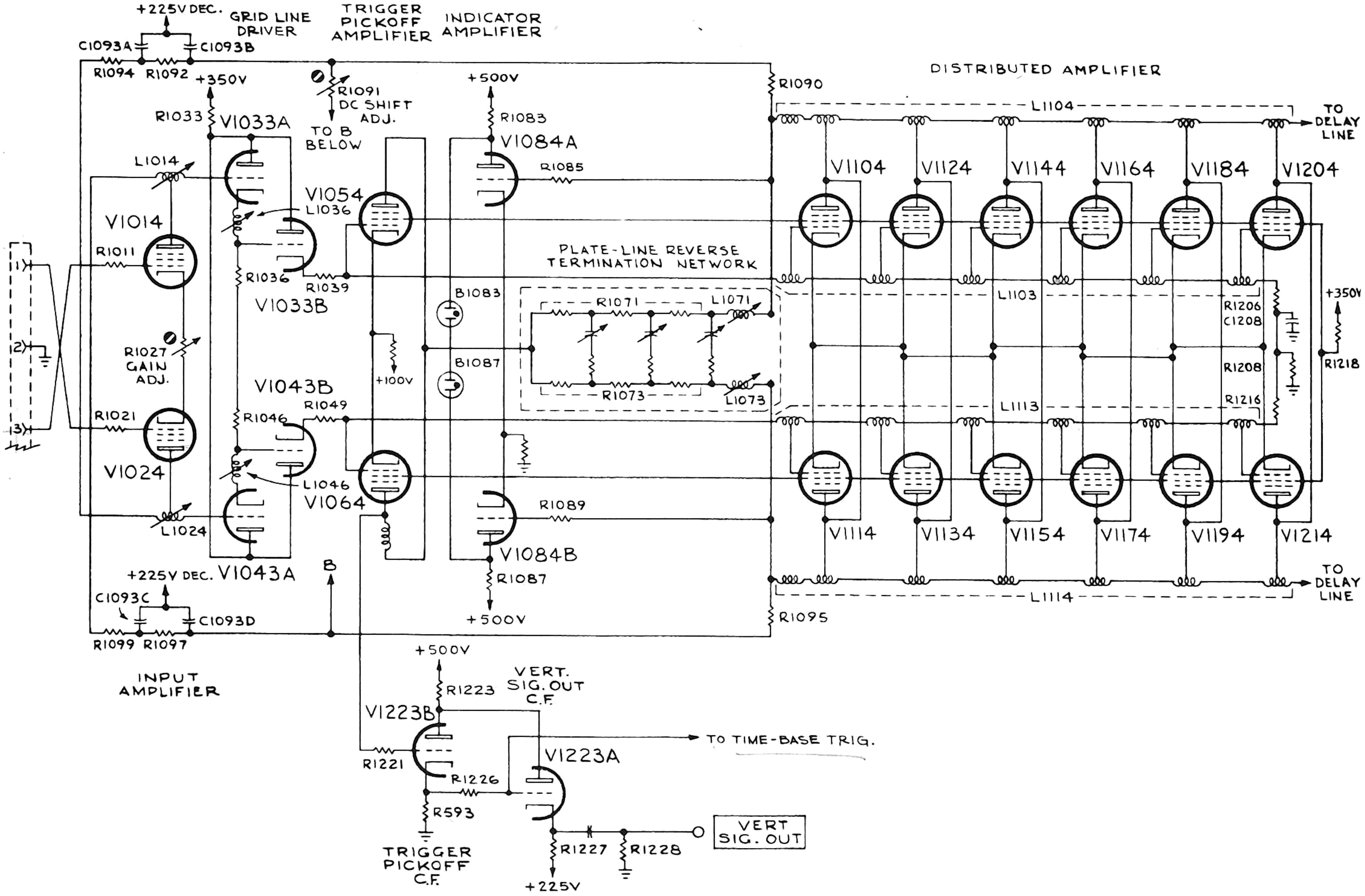


Fig. 4-1. Simplified Type 541A Vertical Amplifier Circuitry.

develop the triggering pulse. This "sample" is obtained from the Trigger Pickoff circuit consisting of the Trigger Pickoff Amplifier V1054 and V1064, the Trigger Pickoff C.F. V1223B.

This "sample" of the vertical signal is also ac-coupled, through V1223A and C1228, to a front-panel binding post labeled VERT. SIG. OUT.

Delay Line

The output signal from the Vertical Amplifier is coupled through the balanced Delay Line to the vertical deflection plates of the crt. The function of the Delay Line is to retard the arrival of the waveform at the deflection plates until the crt has been unblanked and the horizontal sweep started. This delay, as mentioned previously, insures that the very leading edge of fast vertical signals can be observed. The line is adjusted, by means of the variable capacitors across the line, for optimum transient response.

The entire Delay Line, which includes the plate line in the Distributed Amplifier, is reverse-terminated in its characteristic impedance. The Termination Network, shown in the Vertical Amplifier diagram, is designed to dissipate both the dc and signal energy in the line by presenting a constant resistance over the frequency range of the amplifier. The terminating resistors R1071 and R1073 are specially made, wirewound, non-inductive, distributed resistors. The 600 ohms total resistance in each is tapered, or distributed in steps. The largest segment appears at the opposite end. Each step of the resistance is then tuned, by means of the variable capacitors, so that the network will present an optimum load to the line.

HORIZONTAL-DEFLECTION SYSTEM

TIME-BASE TRIGGER

General

The Time-Base Trigger develops a pulse which will start a cycle of action in the Time-Base Generator. To display signals below five megacycles, a TRIGGERING MODE switch allows the operator to select the type of triggered operation most suitable for the waveform to be displayed. A second switch, the TRIGGER SLOPE switch, allows the operator to select the "slope", either positive or negative, which will cause triggered operation of the sweep. To display signals above five megacycles, the Time-Base Trigger is bypassed, and the signal is applied to the Sweep-Gating Multivibrator in the Time-Base Generator. No choice of triggering slope is available in this mode.

Trigger-Input Amplifier

Triggering signals may be developed from several sources. The most common source of triggering signals uses the internal circuitry of the oscilloscope to sample the signal present in the vertical amplifier. Using an internal source of triggering signal, either triggered operation in the various triggering modes or synchronized operation is available.

Triggered or synchronized operation of the time-base circuitry may be produced from an external source. Operation in any one of the available modes is possible with external signals.

In the +Line or —Line positions of the TRIGGER SLOPE switch a voltage at the power line frequency is used to develop the triggering signal.

The Trigger-Input Amplifier is a polarity-inverting, cathode-coupled amplifier. It serves two basic functions in the Time-Base Trigger. First, it provides a source of negative-going signal to drive the following stage. Secondly, by means of the TRIGGERING LEVEL control, it enables the operator to choose the signal level at which triggered operation of the Time Base will occur.

To trigger from a negative-going signal, the grid of the V24A section is connected to the input signal source. The grid of the V24B section is connected to a dc bias source, which is adjustable with the TRIGGERING LEVEL control. This bias voltage establishes the voltage present at the plate under no-signal conditions.

The voltage at the grid of V24A and the voltage at the plate of V24B are in phase with each other; that is, they both go through ac zero in the same direction at the same time. Thus, the V24B section acts as a cathode-follower, and the signal voltage developed across the cathode resistor becomes the input signal to the V24B section.

To trigger from a positive-going signal, the grid of the V24A section is connected to the TRIGGERING LEVEL control, and the grid of the V24B section is connected to the input signal. With this configuration, the voltage at the plate of the V24B section will be 180° out of phase with the input-signal voltage.

In each of the cases outlined above, a negative-going signal is produced at the plate of the V24B section of the Trigger-Input Amplifier irrespective of the polarity of the input signal.

Also, the amplitude of the triggering signal necessary to cause operation of the following stage is determined by the setting of the TRIGGERING LEVEL control.

Trigger Multivibrator

The Trigger Multivibrator is a dc-coupled multivibrator. In the quiescent state, ready to receive a signal, the V45A section is conducting and the plate voltage is down. Since the plate is dc-coupled to the grid of the V45B section, that grid is held below cutoff. With the V45B section cut off its plate voltage is up and no output is developed.

The negative-going portion of the signal from the Trigger-Input Amplifier is required to drive the grid of the V45A section down. As the V45A section grid is driven negative, the current flow through the tube is restricted and the voltage at the plate starts to rise.

The rise in voltage at the plate of the V45A section carries the grid of the V45B section in the positive direction.

The cathodes of both sections are coupled together, and follow the action of the grids. With the V45B section grid going in a positive direction, and the cathode in a negative direction, the V45B section starts to conduct. As the V45B

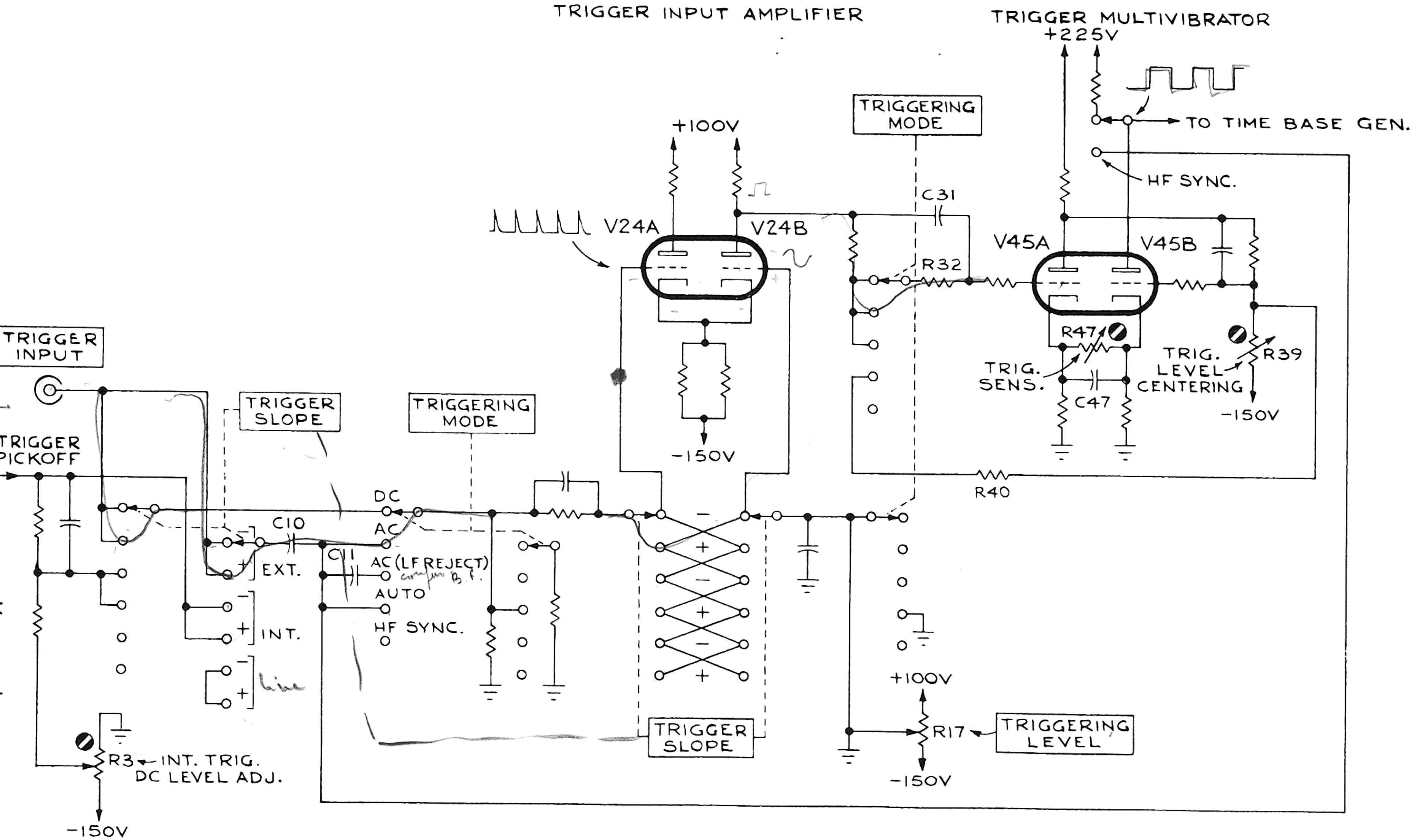


Fig. 4-2. Simplified Type 541A Trigger Circuitry.

section starts to conduct, the cathodes of both sections follow the action of the V45B section grid; hence the cathode voltage starts to rise.

As the V45A section grid goes down and its cathode goes up, it stops conducting. As the V45B section conducts, its plate voltage drops, creating a negative step at the output. This transition occurs rapidly, regardless of how slowly the V45A grid falls.

When the signal applied to the grid of the V45A section goes in a positive direction the action described in the previous paragraphs reverses itself. That is, the V45A section will start to conduct once more, while the V45B section will be cut off.

In the AUTO. position of the TRIGGERING MODE switch the Trigger Multivibrator is converted from a bistable configuration to a recurrent configuration. This is done by coupling the grid circuit of the V45A section to the grid circuit of the V45B section. In addition, the dc coupling between the grid of the V45A section of the Trigger Multivibrator and the plate of the V25B section of the Trigger-Input Amplifier is replaced by ac coupling.

In the AUTO. triggering mode the Trigger Multivibrator will free run in the absence of a triggering signal. For example, assume that the grid of the V45A section is just being driven into cutoff. The voltage at the plate of the V45A section starts to rise, carrying with it the grid of the V45B section. As the voltage at the grid of the V45B section starts to rise, the V45B section starts to conduct.

The rising voltage at the grid of the V45B section is coupled to the grid of the V45A section through R40. The grid of V45A is prevented from rising immediately by the action of C31, which must be charged sufficiently to raise the voltage at the grid of the V45A section above cutoff.

As the V45A section starts to conduct, its plate voltage drops, which in turn lowers the voltage at the grid of the V45B section. The voltage at the grid of V45A starts dropping exponentially toward cutoff. When the V45A section reaches cutoff, the circuit has completed one cycle of its approximately 50-cycle repetition rate.

The Trigger Multivibrator produces a square-wave which is coupled to the Time-Base Generator. This square wave is differentiated in the Time-Base Generator to produce a sharp, negative-going pulse which is used to trigger the Time-Base Generator in the proper time sequence when triggered operation is desired. For synchronized operation of the Time-Base Generator, the TRIGGERING MODE switch is placed in the HF SYNC position. This couples the signal present at the Input of the Time-Base Trigger directly into the Time-Base Generator, and the Time-Base Trigger circuitry is not used in the HF SYNC mode.

TIME-BASE GENERATOR

General

The Trigger circuit produces a negative-going waveform which is coupled to the Time-Base Generator. This waveform is differentiated in the grid circuit of V135A to produce a sharp negative-going triggering pulse to trigger the Time-Base Generator in the proper time sequence. Positive-going pulses are also produced in the differentiation process, but they are not used in the operation of the Time-Base Generator.

The Time-Base Generator consists of three main circuits; a Sweep-Gating Multivibrator, a Miller-Runup Circuit, and a Hold-off Circuit. The Sweep-Gating Multivibrator consists of V135A, V145 and the cathode follower V135B. The essential components of the Miller-Runup Circuit are the Miller tube V161, the Runup C. F. V173, the On-Off Diodes V152, the Timing Capacitor C160 and the timing Resistor R160. The Holdoff circuit consists of the Hold-Off C.F. s V183A-V133B, the Holdoff Capacitor C180 and the Holdoff Resistors R181-R180. Essential circuitry of the Time-Base Generator is shown in Fig. 4-3.

Sweep-Gating Multivibrator

The Sweep-Gating Multivibrator operates as a bistable circuit. In the quiescent state V135A is conducting and its plate is down. This cuts off V145 through V135B and divider R141-R143, and the common cathode resistor R144. With V145 cutoff, its plate is clamped about 3 volts below ground by conduction of diode V152A and B through R147 and R148. Conduction of the lower diode V152B through the Timing Resistor R160 then clamps the grid of the Miller tube at about —3.5 volts.

Miller-Runup Circuit

The quiescent state of the Miller circuit is determined by a dc network between plate and grid. This network consists of the neon glow tube B167, the Runup C.F. V173 and the On-Off Diodes V152. The purpose of this network is to establish a voltage at the plate of the Miller tube of such a value that the tube will operate above the knee, and thus over the linear region, of its characteristic curve. This quiescent plate voltage is about +43 volts.

Sweep Generation

If the STABILITY and TRIGGERING LEVEL controls are now adjusted for triggered operation, a negative trigger will drive the grid of V135A below cutoff and force the Sweep-Gating Multivibrator into its other state in which V145 is the conducting tube. As V145 conducts its plate drops, cutting off the On-Off Diodes V152. Any spiking that may occur during this transition is attenuated by the C150-R150 network.

With V152 cut off, the grid of the Miller tube and the cathode of the Runup C.F. are free to seek their own voltages. The grid of the Miller tube then starts to drop, since it is connected to the —150 volt bus through the Timing Resistor R160. The plate of the Miller tube starts to rise, carrying with it the grid and cathode of V173. This raises the voltage at the top of the Timing Capacitor C160, which in turn pulls up the grid of the Miller tube and prevents it from dropping. The gain of the Miller tube, as a Class A amplifier, is so high that the voltage coupled back through C160 keeps the grid constant within a fraction of a volt.

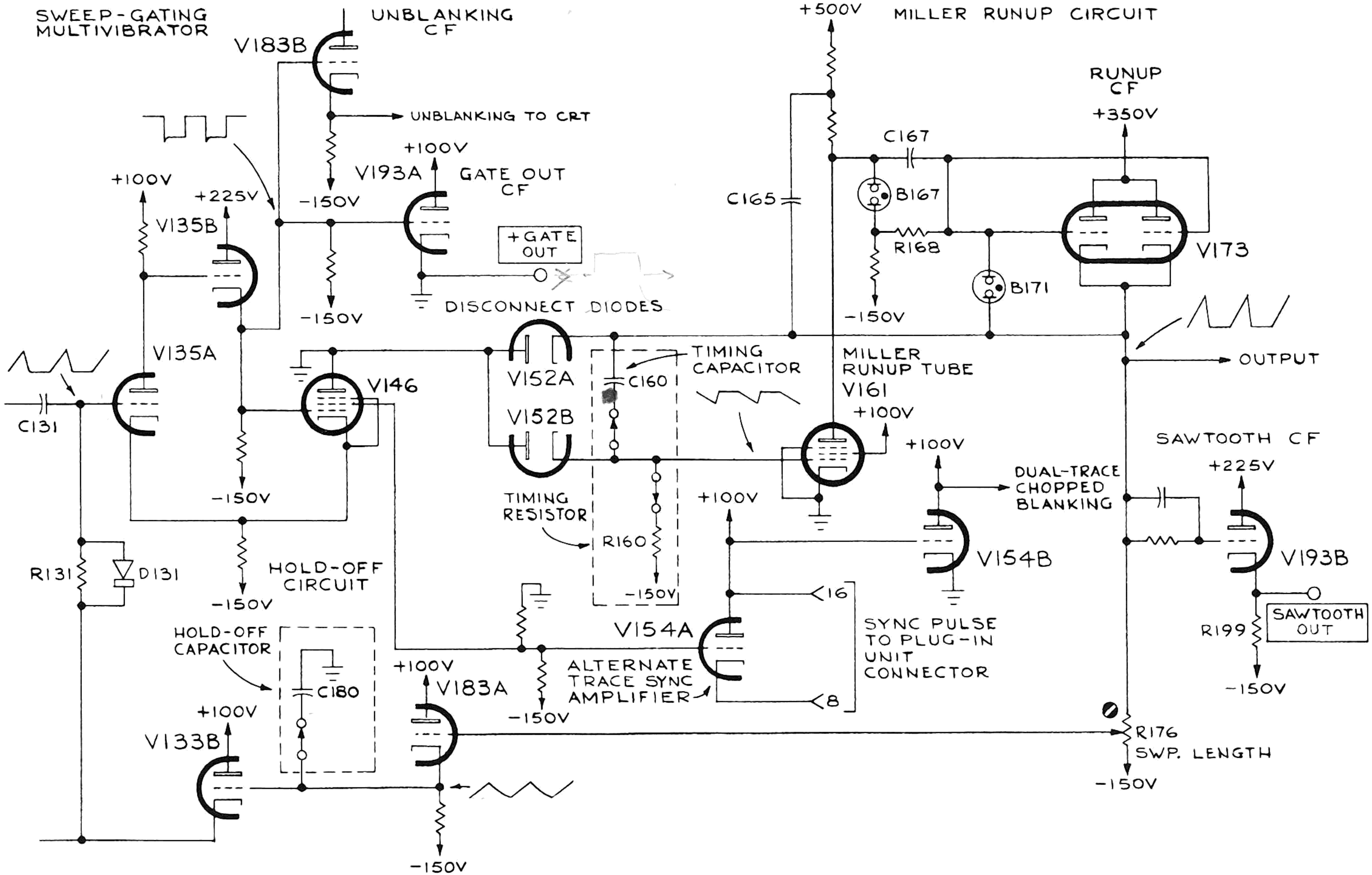


Fig. 4-3. Simplified Type 541A Time-Base Generator Circuit.

The Timing Capacitor then starts charging with current from the —150 volt bus. This charging current flows through the Timing Resistor R160. Since the voltage at the grid of the Miller tube remains essentially constant, the voltage drop across the Timing Resistor remains essentially constant. This provides a constant source of current for charging C160. By this action C160 charges linearly, and the voltage at the cathode of V173 rises linearly. Any departure from a linear rise in voltage at this point will produce a change in the voltage at the grid of the Miller tube in a direction to correct for the error.

Timing Switch

The linear rise in voltage at the cathode of V173 is used as the sweep time-base. Timing Capacitor C160 and Timing Resistor R160 are selected by the TIME/CM switch SW160. R160 determines the current that charges C160. By means of the TIME/CM switch both the size of the capacitor being charged and the charging current can be selected to cover a wide range of sawtooth slopes (sweep rates). For high speed sweeps bootstrap capacitor C165 helps supply current to change the stray capacitance at the plate of the Miller tube. This permits the plate voltage to rise at the required rate.

If uncalibrated sweep rates are desired, the VARIABLE TIME/CM (red knob) control may be turned away from the CALIBRATED position. This control, R160Y, varies the sweep rate over a $2^1/_2$ to one range. Switch 160B is ganged with the VARIABLE control in such a way that the UNCALIBRATED light comes on when the control is turned away from the CALIBRATED position.

Sweep Length

As explained previously, the sweep rate (the rate at which the spot moves across the face of the crt) is determined by the timing circuit C160 and R160. The length of the sweep (the distance the spot moves across the face of the crt), however, is determined by the setting of the SWP. LENGTH control R176. This will increase the voltage at the grid and cathode of V183A and at the grid and cathode of V133B. As the voltage at the cathode of V133B rises, the voltage at the grid of V135A will rise. When the voltage at this point is sufficient to bring V135A out of cutoff, the multivibrator circuit will rapidly revert to its original state with V135A conducting and V145 cut off. The voltage at the plate of V145 rises, carring with it the voltage at the diode plate V152A. The diode then conducts and provides a discharge path for C160 through R147 and R148 and through the resistance of the cathode circuit of V173. The plate voltage of the Miller Tube now falls linearly, under feedback conditions essentially the same as when it generated the sweep portion of the waveform except for a reversal of direction. The resistance through which C160 discharges is much less than that of the Timing Resistor (through which it charges). The capacitor current for this period will therefore be much larger than during the sweep portion, and the plate of the Miller Tube will return rapidly to its quiescent voltage. This produces the retrace portion of the sweep sawtooth during which time the crt beam returns rapidly to its starting point.

Holdoff

The Holdoff Circuit prevents the Time-Base Generator from being triggered during the retrace interval. That is, the Holdoff allows a finite time for the Time-Base circuits to regain a state of equilibrium after the completion of a sweep.

During the trace portion of the sweep sawtooth, the Holdoff Capacitor C180 charges through V183A, as a result of the rise in voltage at the cathode of V183A. At the same time the grid of V135A is being pulled up, through V133B, until V135A comes out of cutoff and starts conducting. As mentioned previously, this is the action that initiates the retrace.

At the start of the trace interval C180 starts discharging through the Holdoff Resistor R181. The time constant of this circuit is long enough, however, so that during the retrace interval (and for a short period of time after the completion of the retrace) C180 holds the grid of V135A high enough so that it cannot be triggered. However, when C180 discharges to the point where V133B is cutoff, it loses control over the grid of V135A and this grid returns to the level established by the STABILITY control. The holdoff time required is determined by the size of the Timing Capacitor. For this reason the TIME/CM switch changes the time constant of the Holdoff Circuit simultaneously with the change of Timing Capacitors. (In the μSEC positions of the TIME/CM switch R181 is shunted by either R180A or R180B, shown on the Timing Switch diagram.)

Stability

The operational mode of the Time-Base Generator is determined by the setting of the STABILITY control R110. By means of this control the sweep can be turned off or adjusted for triggered operation. The STABILITY control, through cathode follower V133A, regulates the grid level of V135A.

For triggered operation, the STABILITY control is adjusted so that the grid of V135A is just high enough to prevent the Sweep-Gating Multivibrator from free running. Adjusted in this manner a sweep can only be produced when an incoming negative trigger pulse drives the grid of V135A below cutoff.

Moving the arm of the STABILITY control toward ground, (ccw rotation), but not so far as to actuate the PRESET switch, will raise the grid level of V135A and prevent the Sweep-Gating Multivibrator from being triggered. This action turns off the sweep. Moving the arm toward —150 volts drops the grid of V135A to the point where the discharge of the Holdoff Capacitor C180 can switch the multivibrator. Adjusted in this manner, the Sweep-Gating Multivibrator will free run and produce a recurrent sweep.

When the STABILITY control is turned full ccw to the PRESET position, R110 is switched out of the circuit and R111 is switched in. This control, a front-panel screwdriver adjustment labeled PRESET ADJUST, provides a fixed dc voltage for the grid of V135A. When properly adjusted, PRESET operation can be used for most triggering applications. Where triggering may be difficult, however, the manual STABILITY control R110 should be used.

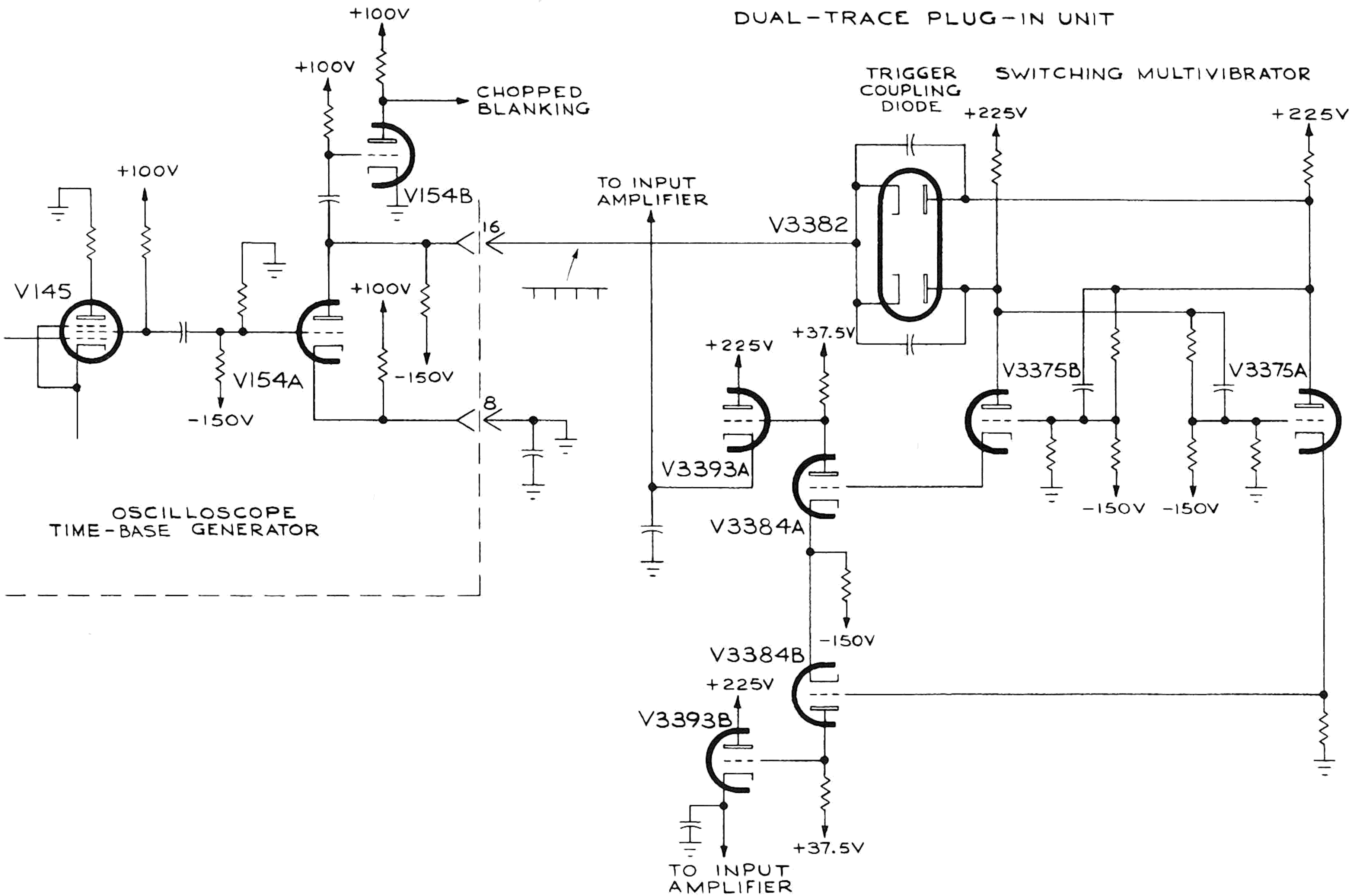


Fig. 4-4. Simplified Dual-Trace Operation.

Unblanking

The positive rectangular pulse at the cathode of V135B in the Sweep-Gating Multivibrator circuit is coupled through a cathode follower V183B to the grid supply for the crt. This pulse, whose start and duration are coincident with the rising portion of the sawtooth sweep waveform, pulls up the grid of the crt. This unblanks the crt during the trace portion of the sweep and permits the trace to be observed.

Output Waveforms

The positive pulse coupled to the crt circuit for unblanking is also coupled through a cathode follower V193A to a front-panel binding post labeled + GATE OUT. This positive gate waveform starts at ground and rises to about +20 volts.

The sweep sawtooth voltage at the cathode of V173 is coupled through a cathode follower V193B to a front-panel binding post labeled SAWTOOTH OUT. This waveform, which starts at about ground, provides a 150-volt linear rise in voltage.

Dual-Trace Sync and Blanking

Synchronizing pulses for dual-trace plug-in preamplifiers are supplied by V154A. When multivibrator tube V145 cuts off, a sharply differentiated positive pulse is developed at its screen. This pulse, coupled to the grid of V154A, produces a negative trigger at the plate of V154A. This trigger then switches the multivibrator in the dual-trace unit employed for alternate sweeps.

When the dual-trace multivibrator is connected for free running operation to produce chopped sweeps, a negative pulse is coupled from the multivibrator to the grid of V154B. The resultant positive pulse at the plate of V154B is coupled to the cathode of the crt to blank out the beam during switching. Refer to the manual for the dual-trace unit for a detailed description of the switching multivibrator.

HORIZONTAL AMPLIFIER

The Horizontal Amplifier converts the single-ended sawtooth output of the Time-Base Generator into a push-pull signal suitable for driving the horizontal plates of the crt. The gain of the amplifier may be varied by a factor of five by means of the 5X magnification switching. In addition, controls are provided for horizontal positioning and adjustment of the horizontal linearity.

Input Circuit

The sawtooth waveform from the Time-Base Generator is coupled to the Input Cathode Follower through the R330, C330 network. This network attenuates the input signal and provides a means of compensating the input circuitry for optimum frequency response. During calibration C330 is adjusted for best response to a square wave.

The HORIZONTAL POSITION and VERNIER controls adjust the dc level at the grid of V343A. This change in dc level changes the dc level on the signal path through the amplifier, thus changing the dc voltage applied to the crt horizontal deflection plates and affecting the horizontal positioning.

Input Amplifier

Coupling between the Input CF and the Driver CF is made by the 5X MAG position of the HORIZONTAL DISPLAY switch. When this is not in the 5X MAG position the signal from the Input CF must pass through the network formed by C348 in parallel with the series combination, R348 and R349. R348, a variable resistor, allows the operator to adjust the length of the time base by varying the attenuation applied to the signal. C348, a variable capacitor, is adjusted to provide optimum linearity of the time base on the fastest time bases.

This network attenuates the signal by a factor of five. To provide magnification of the time base the network is removed when the HORIZONTAL DISPLAY switch is turned to the 5X MAG position.

The gain of the Horizontal Amplifier is controlled by a negative feedback circuit. The signal appearing at the left-hand deflection plate is fed back to the input of the Driver C.F. R348 is an adjustable resistor which allows the operator to vary the dc voltage applied to the feedback loop.

By changing the dc voltage at this point the operator can adjust the position of the unmagnified sweep so that it will correspond with the position of the magnified sweep.

The output waveform from the Horizontal Amplifier is taken from V364A and V384A. The cathodes of these tubes are connected through a network which includes the Mag. Gain control. This control enables the operator to adjust the gain of the Horizontal Amplifier so that the ratio between the magnified and unmagnified sweeps is correct. C375, in parallel with the Mag. Gain control, has considerable effect on the linearity at the beginning of the time base, and is adjusted while displaying a signal with a high repetition rate.

Part of the signal appearing at the plate of the output amplifiers is used to drive the Output CFs. Note that the cathode of V364B is connected to the plate of V398, a pentode. The function of the Output CFs is to drive the capacitance of the horizontal deflection plates and the associated wiring. To assure a sufficient flow of current at fast time bases, the pentode V398 is used to supply current to the Output CF which drives the negative-going, or left-hand deflection plate. A pentode is chosen as a current booster, since its plate characteristic provides a flat-topped pulse of current. The pulse to drive the grid of the pentode is derived from the waveform at the right-hand deflection plate. This waveform is differentiated by the C390, R390 network before being applied to the grid. Its amplitude is thus proportional to the time base. For the fastest time bases, the tube current is several times normal, but at the reduced duty cycle of the time base, well within the dissipation rating of the tubes.

Bootstrap capacitors C364 and C384 are used to help supply the necessary charging current for fast time bases. During calibration these two capacitors are adjusted on the fastest time base for optimum linearity.

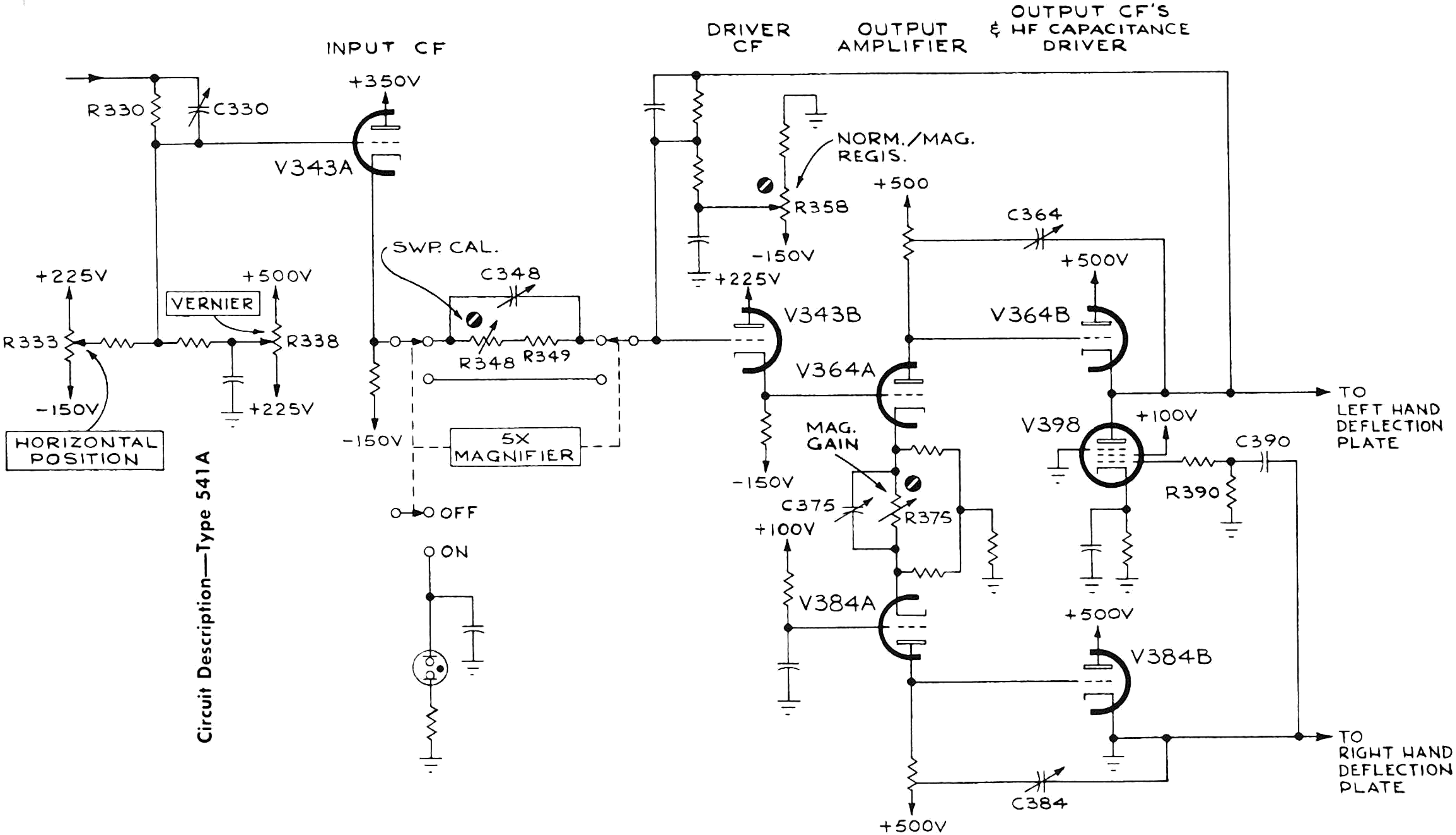


Fig. 4-5. Simplified Type 541A Horizontal Amplifier.

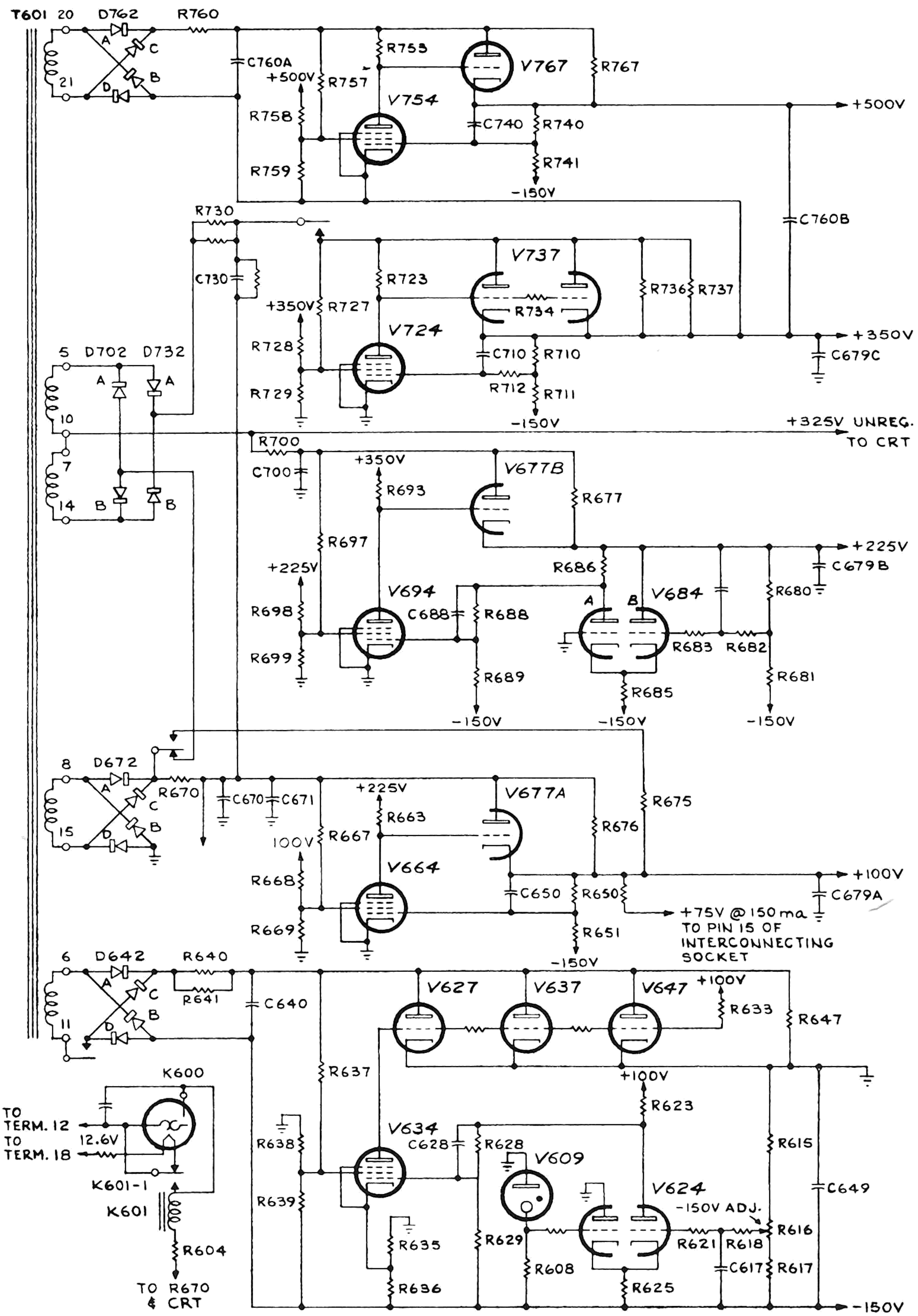


Fig. 4-6. Simplified Type 541A Low-Voltage Power Supply.

EXTERNAL HORIZONTAL AMPLIFIER

When the HORIZONTAL DISPLAY swtich, SW348, is in either the EXT. HORIZ. ATTEN X1 or X10 positions, the HORIZ. INPUT connector connects to an auxiliary amplifier which uses the tubes and circuits of phase inverters.

External sweep signals are applied to the grid of V303A directly or through a X10 attenuator for the circuit in-phase amplification.

The signal applied to the V303A grid is cathode coupled to V314A, which, with V314B, is a cathode-coupled, grounded-grid amplifier. Gain of this amplifier can be adjusted by varying R314, EXTERNAL HORIZ. ATTEN., which determines the amount of cathode coupling. The two cathodes must be at the same dc voltage, or variation of R314 will change the dc level. R307, labeled Ext. Horiz. DC Bal on the chassis, can be adjusted so that the cathodes of V314A and V314B are at the same voltage.

Plate output from V314B is connected to the Input CF V343A in the Horizontal Sweep Amplifier when the HORIZONTAL DISPLAY switch is in either the EXT. HORIZ. ATTEN X1 or X10 positions.

Note that the external sweep signal must not have a dc component of its own or the dc balance will be upset, and adjustment of the 10-1 gain control will position the trace horizontally.

LOW VOLTAGE POWER SUPPLY

Power Transformer

Plate and filament power for the tubes in the Type 541A are furnished by a single power transformer, T601. The primary has two equal windings which may be connected in parallel for 117-volt operation, or in series for 234-volt operation. The power supply will maintain regulation over line voltage ranges of 105 and 125 volts, or 210 to 250 volts, rms, 50-60 cycles. Bridge rectifiers are employed for the five separate, full-wave, power supplies. The five supplies furnish regulated output voltages of —150, +100, +225, +350 and +500 volts.

—150-Volt Supply

Reference voltage for the —150 volt supply is furnished by a gas diode voltage-reference tube V609. This tube, which has a constant voltage drop, establishes a fixed potential of about —87 volts at the grid of V624A, one-half of a difference amplifier. The grid voltage for the other half of the difference amplifier, V624B, is obtained from a divider consisting of R616, R617, and R618. The —150 ADJ. control R616 determines the percentage of total voltage that appears at the grid of V624B and thus determines the total voltage across the divider. This control is adjusted so that the output voltage is exactly —150 volts.

If line-voltage or load fluctuations tend to change the output voltage, an error signal exists between the two grids of the difference amplifier. The error signal is amplified in V624B and V634 and applied to the grids of the series tubes, V627, V637 and V647. The resulting changes in voltage at the plates of the series tubes, which will be in a direction to compensate for any change in output voltage, is coupled through the rectifiers to the output to keep this voltage constant. Capacitors C617 and C628 improve the ac gain of the feedback loop to increase the response of the regulator circuit to sudden changes in output voltage.

A small amount of unregulated bus ripple is coupled to the screen of V634 through R637. The phase of the amplified ripple voltage at the plate of V634 is such as to cancel most of the ripple on the —150 volt bus.

+100-Volt Supply

The 100-volt supply is regulated by comparing to ground (the cathode of V664) the voltage of a point near ground potential obtained from the divider R650—R651 connected between the +100-volt bus and the regulated —150 volt supply. Any error voltage that exists is amplified and inverted in polarity by V664 and coupled through the cathode follower V677A that is opposite in polarity to the ripple at the plate; this tends to cancel the ripple at the cathode and hence on the +100-volt bus. This same circuit also improves the regulation in the presence of line-voltage variations.

+225-Volt Supply

Rectified voltage from terminals 10 and 14 of the power transformer is added to the voltage supplying the +100 volt regulator to furnish power for the +225 volt regulator. This supply is regulated by comparing to ground (the grid of V684A) the voltage of a point near ground obtained from the divider R680-R681 connected between the +225 volt bus and the regulated —150 volt supply. Any error voltage that exists between the grids of the difference amplifier (V684) is amplified in both V684 and V694, and coupled through the cathode follower V677B to the +225 volt bus. The change in voltage at the cathode of V677B, due to the regulator action, will be opposite in polarity to the original error signal and will thus tend to keep the output constant. This supply also furnishes an unregulated output of about +325 volts for the oscillator in the crt high-voltage supply. It is unnecessary to regulate this voltage as the crt supply has its own regulator circuits.

+350-Volt Supply

Rectified voltage from terminals 5 and 14 of T601 is added to voltage supplying the +100 volt regulator to furnish power for the +350 volt regulator. This supply is regulated by comparing to ground the voltage of a point near ground obtained from the divider R710-R711 that is connected between the +350 volt bus and the regulated —150 volt supply. The operation of the regulated circuit is the same as that described for the +100 volt supply.

+500-Volt Supply

Rectified voltage from terminals 20 and 21 of T601 is added to the regulated side of the +350 volt supply to furnish power for the +500 volt regulator. This supply is regulated by comparing to the regulated +350 volts the voltage of a point near +350 obtained from the divider R740-R741 connected between the +500 volt bus and the regulated —150 volt supply. The regulator action of this circuit is the same as that described for the +100-volt supply.

Time Delay

A Time-Delay relay K600 delays the application of dc voltages to the amplifier tubes in the instrument for about 25 seconds. This delay is to allow the tube heaters time to bring the cathodes up to emission temperature before operating potentials are applied.

CRT CIRCUIT

Cathode Ray Tube Control Circuits

The INTENSITY control R826 varies the voltage at the grid of the crt to control the beam current. The FOCUS control R856 varies the voltage at the focusing ring to focus the trace. The ASTIGMATISM control R864 varies the voltage at the astigmatism anode to focus the spot in both dimensions simultaneously. The GEOM. ADJ. R861 varies the field the beam encounters as it emerges from the deflection system to control the linearity at the extremes of deflection.

The CRT CATHODE SELECTOR switch SW848 connects the cathode of the crt through C848 to either a rear panel binding post labeled EXTERNAL CRT CATHODE or to the plate of V154B in the Time-Base Generator circuit. When this switch is in the DUAL-TRACE CHOPPED BLANKING position, the cathode of the crt is connected to receive positive pulses from the Time-Base Generator circuit to blank the crt during switching while operating a dual-trace plug-in unit in the chopped mode.

When SW848 is in the EXTERNAL CRT CATHODE position, the cathode circuit of the crt is connected to the binding post mentioned previously. A bare bus bar normally connects the binding post to ground. When intensity modulation of the beam is desired, the bus bar can be removed so that the modulating signal can be coupled to the crt cathode.

High-Voltage Supply

A single 60-kc Hartley oscillator furnishes power for the three power supplies that provide accelerating potentials for the crt. The main components in the Oscillator circuit are the pentode V800 and the primary of T801 tuned by C808.

A half-wave rectifier V862 provides —1350 volts for the crt cathode. A half-wave voltage tripler circuit, V832, V842 and V852, provides +8650 volts for the post-anode accelerator. This provides a total accelerating voltage of 10,000 volts. Both supplies are tied to the +100 volt regulated supply through the decoupling filter R801-C801.

A floating half-wave rectifier V822 furnishes bias voltage (about —1450 volts) for the crt grid. This floating grid supply, independent of the cathode supply, is required in order to provide dc-coupled unblanking to the crt grid. All three supplies employ capacitor-input filters.

The —1350 volt cathode supply is regulated by comparing to the —150 volt regulated supply (the cathode of V814B) a voltage near —150 volts obtained from a tap on the divider connected between the decoupled +100 volt bus and the —1350 volt bus. The total resistance of the divider, and hence the voltage across the divider, is determined by the setting of R840 labeled HV Adj. When this control is properly adjusted, the voltage at the HV Adj. Test Point will be exactly —1350 volts.

If variations in loading should tend to change the voltage on the —1350 volt bus, an error signal will exist between the grid and cathode of V814B. The error signal will be amplified by V814B and V814A; the output of V814A varies the screen voltage of the oscillator tube V800, thereby controlling its output.

The +8650 volt supply and the negative bias supply are regulated indirectly, as the output voltage of all three supplies is proportional to the output of the Oscillator circuit.

Unblanking

As mentioned previously, dc-coupled unblanking is accomplished by employing separate power supplies for the grid and cathode of the crt. The unblanking pulses from the Time-Base Generator are transmitted to the crt grid through the cathode follower V183B and the floating grid supply.

At the faster sweep rates the stray capacitance in the circuit makes it difficult to pull up the floating supply fast enough to unblank the crt in the required time. To overcome this, an isolation network composed of C827, C828, C829, R827 and R829 is employed. By this arrangement the fast leading edge of the unblanking pulse is coupled through C834 to the grid of the crt. For short-duration unblanking pulses, at the faster sweep rates, the power supply itself is not appreciably moved.

The longer unblanking pulses, at the slower sweep rates, charge the stray capacitance in the circuit through R834. This pulls up the floating supply and holds the grid at the unblanked potential for the duration of the unblanking pulse.

Calibrator

The Calibrator is a square-wave generator producing an output at approximately 1 kc which is available at the front panel CAL. OUT connector. It consists of V875 and V885A comprising a multivibrator, connected so as to switch the cathode follower V885B between two operating states, cutoff and conduction.

During the negative portion of the multivibrator waveform the grid of V885B is driven well below cutoff and its cathode rests at ground potential. During the positive portion of the waveform V875 is cut off and its plate rests slightly below +100 volts. The voltage at the grid of V885B when this tube is cut off, is determined by the setting of the Cal. Adj. control R879, part of the divider connected between +100 volts and ground.

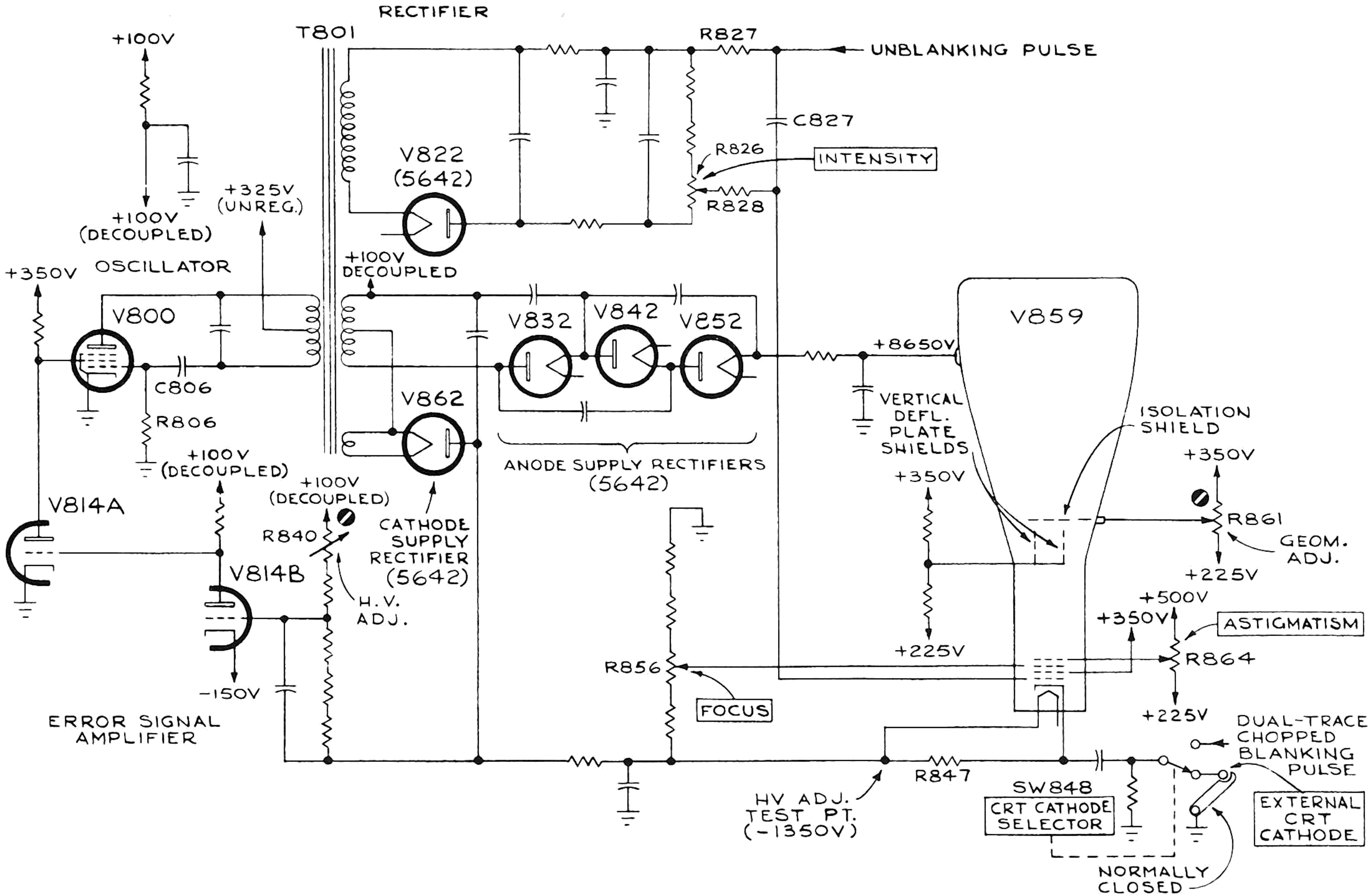


Fig. 4-7. Simplified Type 541A CRT Circuit.

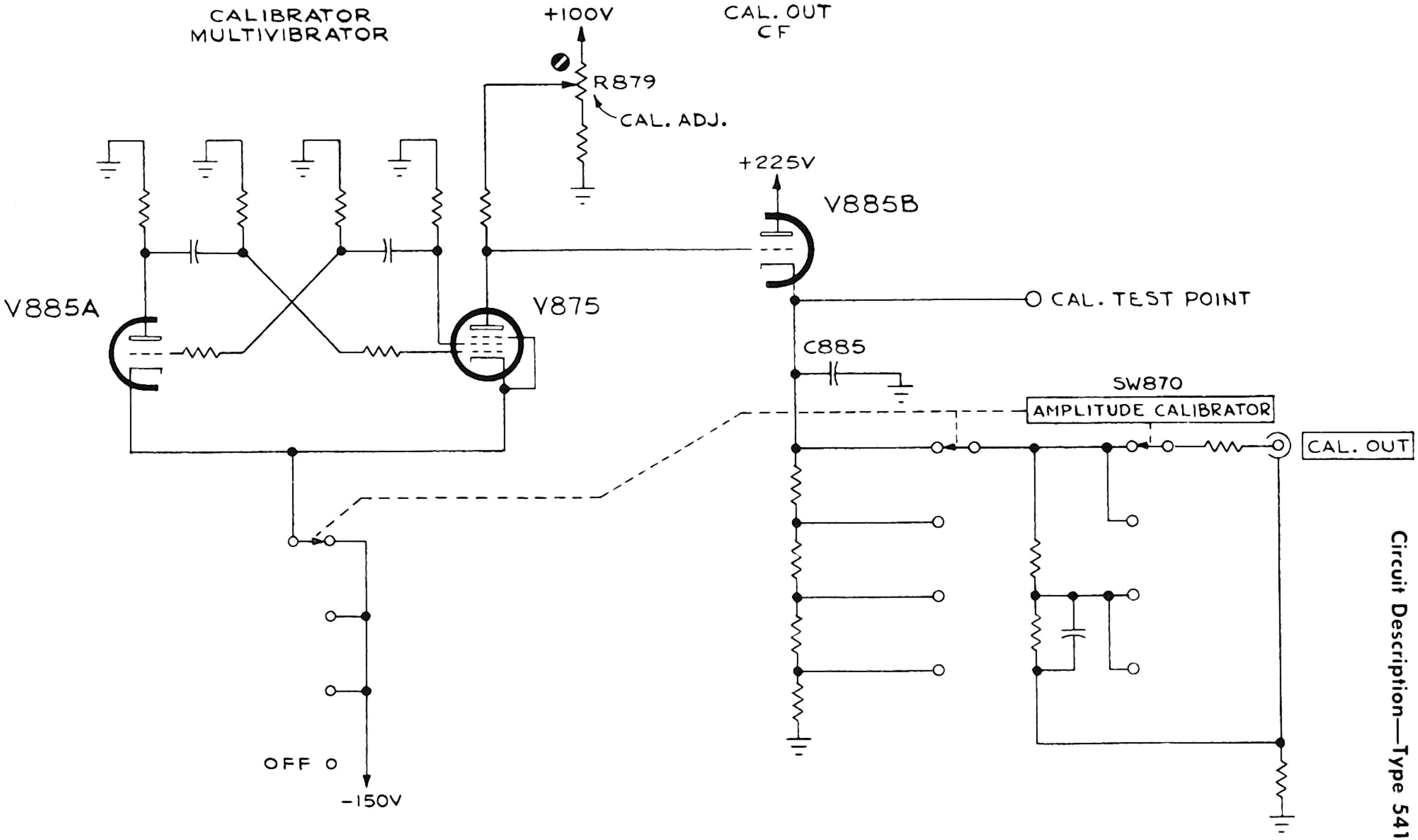
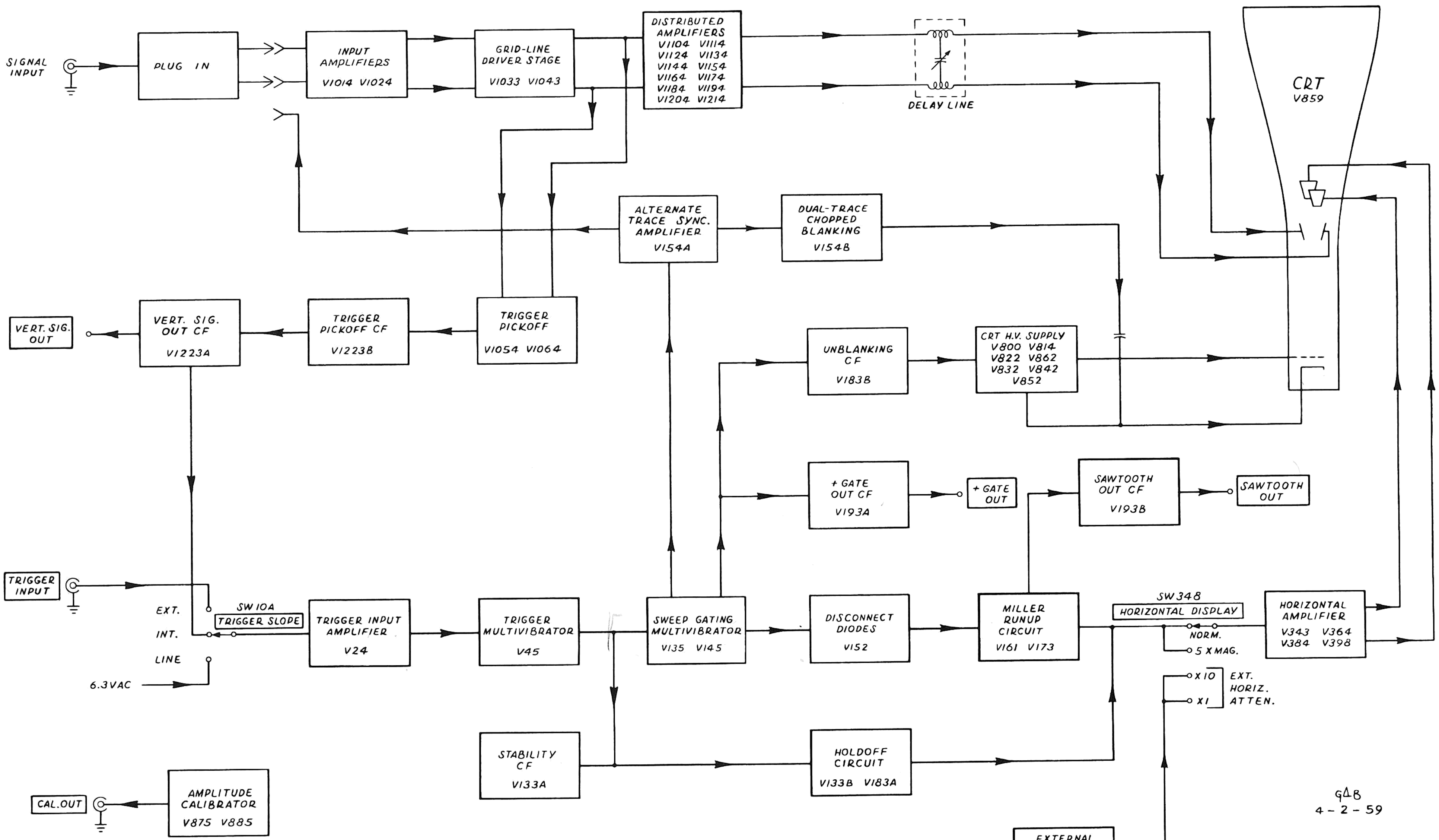
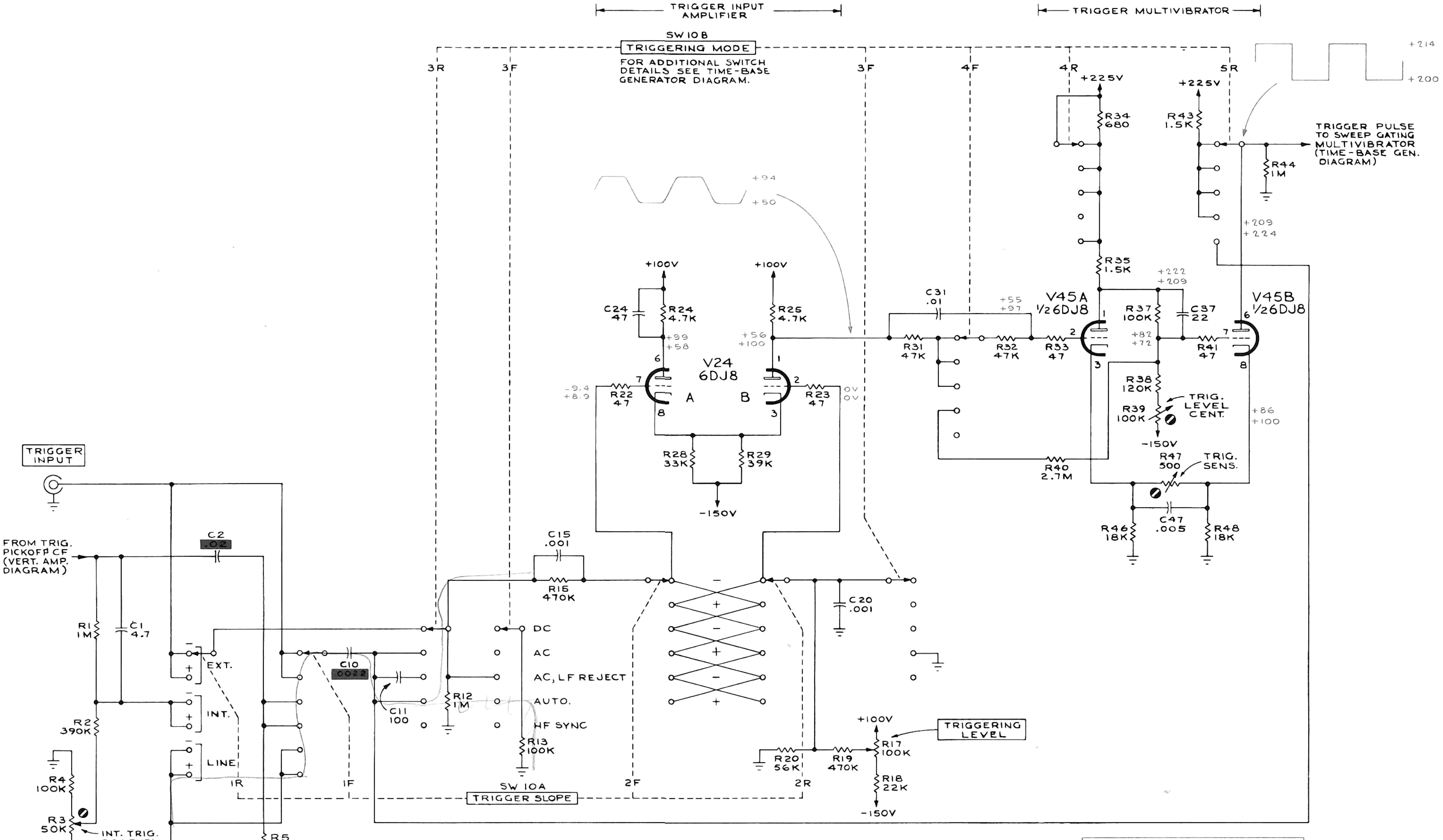


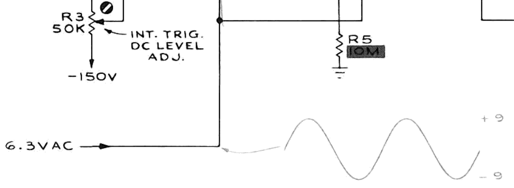
Fig. 4-8. Simplified Type 541A Calibrator.



BLOCK DIAGRAM

TYPE 541A OSCILLOSCOPE





IMPORTANT

WAVEFORMS ARE IDEALIAZED BUT CLOSELY APPROXIMATE THOSE TO BE FOUND IN THIS INSTRUMENT PROVIDED CONTROLS ARE SET AS INDICATED BELOW AND ON EACH SCHEMATIC. VOLTAGE READINGS, IF TAKEN WITH A VTVM, WILL BE WITHIN ±10% OF THE INDICATED VALUE. BEFORE STARTING TO CHECK THIS INSTRUMENT THE FOLLOWING CONTROLS SHOULD BE SET AND NOT DISTURBED UNLESS OTHERWISE NOTED ON SCHEMATICS BEING USED. RETURN CONTROLS TO THE POSITIONS LISTED BELOW BEFRE MOVING TO THE NEXT SCHEMATIC

AMPLITUDE CALIBRATOR	OFF
HORIZONTAL DISPLAY	TIME-BASE (NORM.)
VARIABLE (TIME/CM)	CW (CALIBRATED)
TIME/CM	1 mSEC
TRIGGERING MODE	AC
TRIGGER SLOPE	+ LINE
TRIGGERING LEVEL	CENTERED
STABILITY	PRESET

WAVFORMS AND VOLTAGE READINGS WERE OBTAINED WITH CONTROLS SET AS FOLLOWS:

TRIGGERING LEVEL

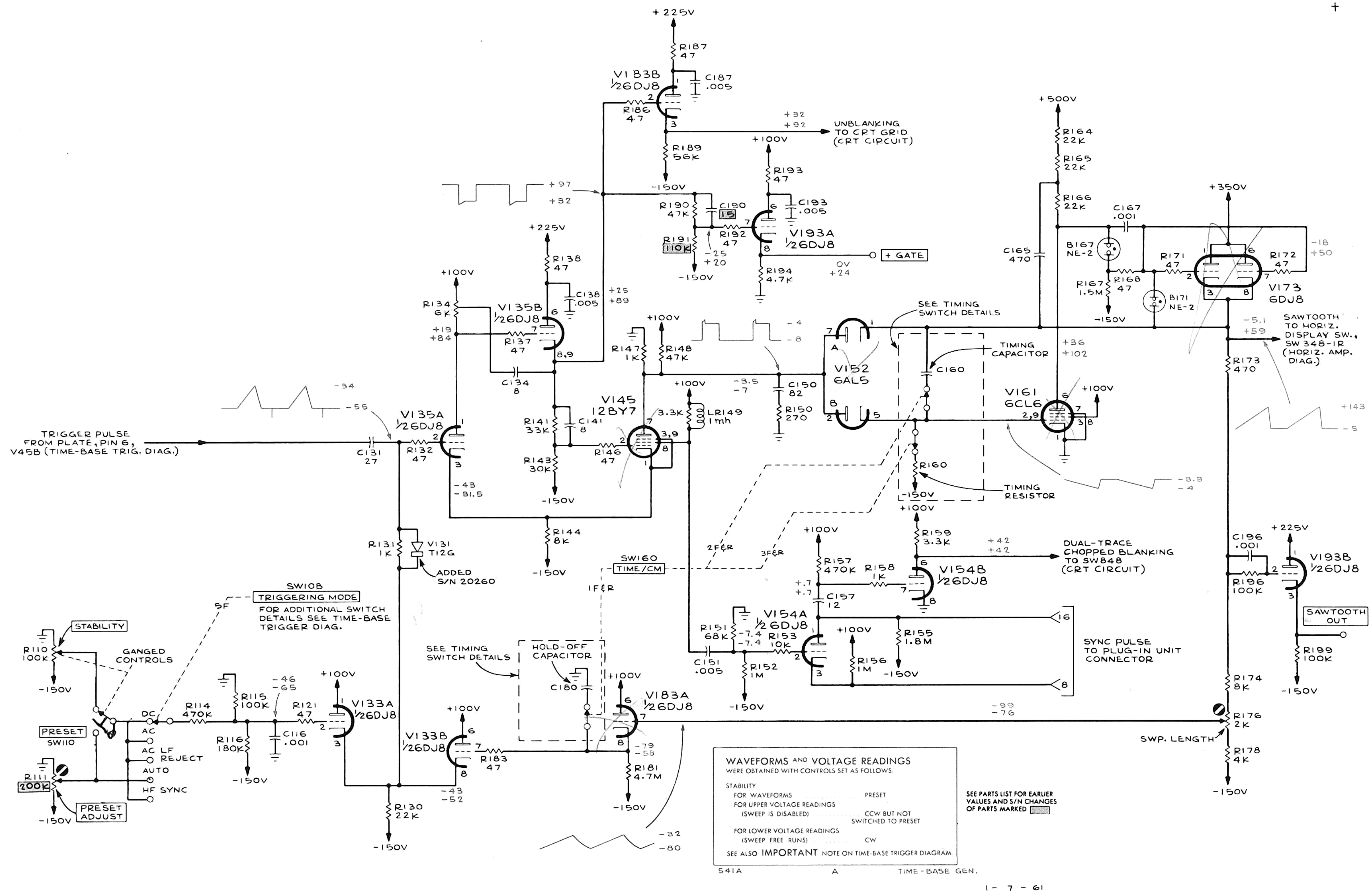
FOR WAVEFORMS	CENTERED
FOR UPPER VOLTAGE READINGS	CCW
FOR LOWER VOLTAGE READINGS	CW

SEE ALSO IMPORTANT NOTE ON THIS DIAGRAM.

541A TIME-BASE TRIG.

MRH
1263

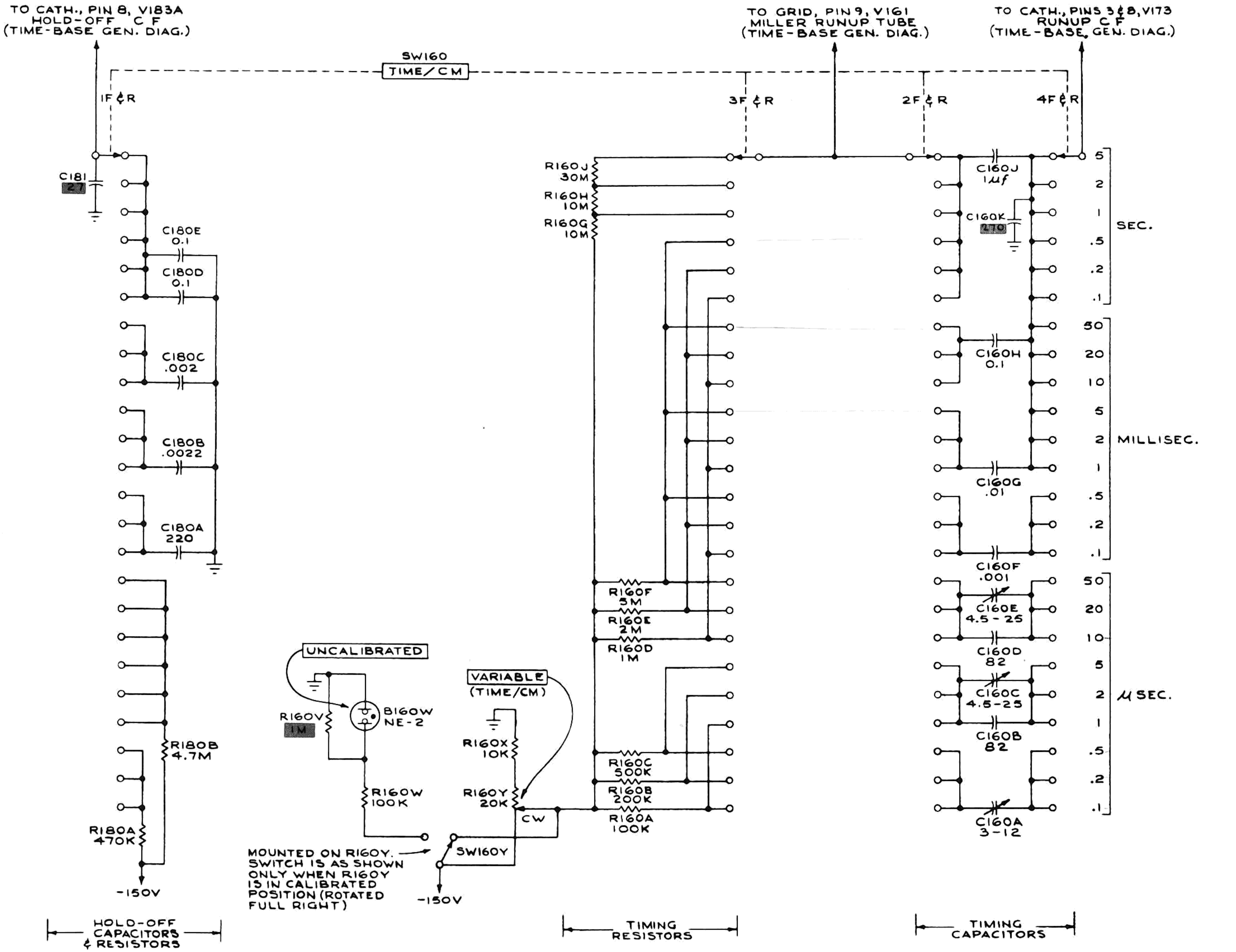
TIME-BASE TRIGGER



TYPE 541A OSCILLOSCOPE

D_2

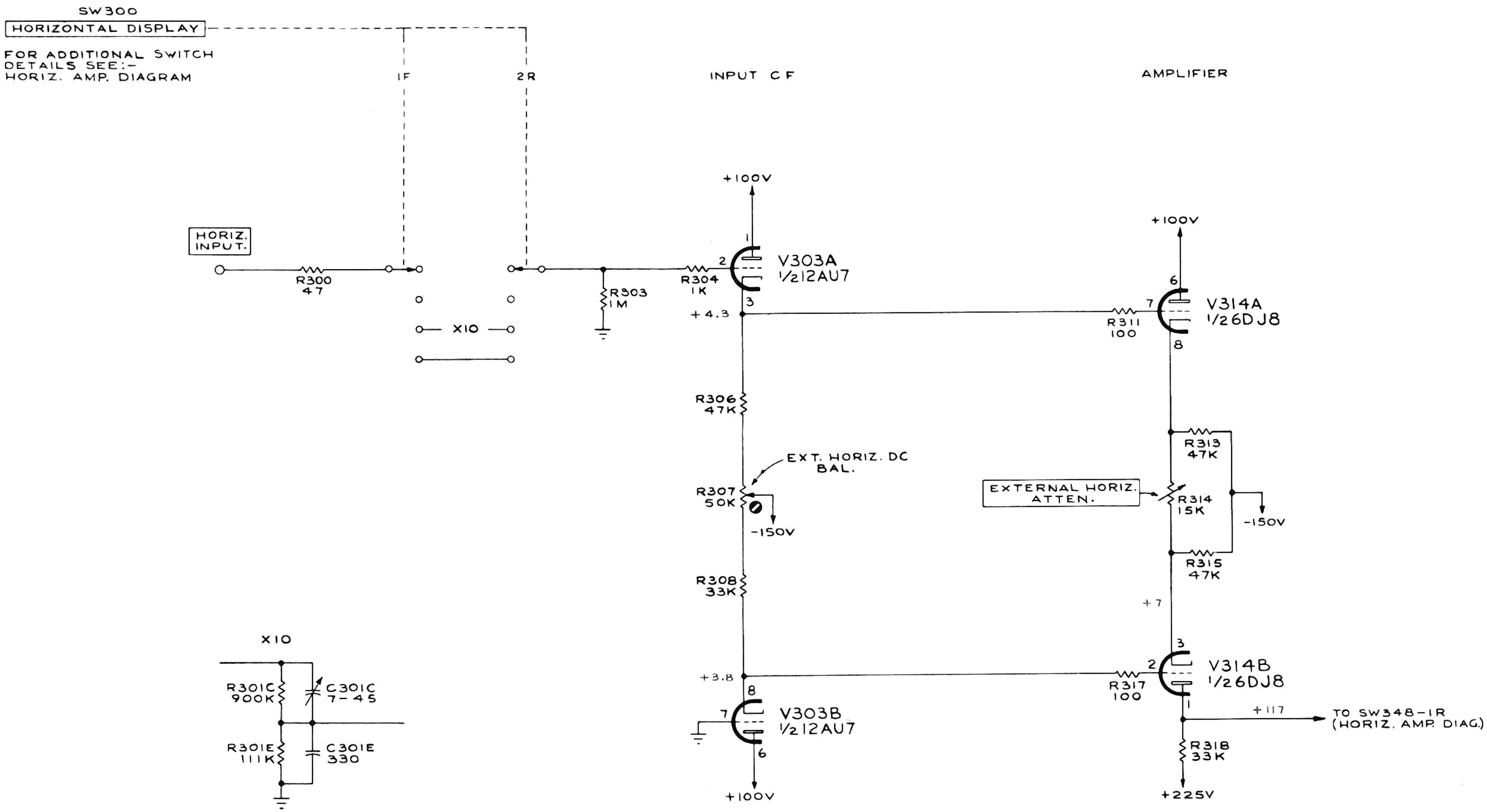
TIME-BASE GENERATOR



MRH
1-9-61

TYPE 541A OSCILLOSCOPE

TIMING SWITCH



VOLTAGE READINGS WERE OBTAINED WITH CONTROLS SET AS FOLLOWS:	
EXTERNAL HORIZONTAL INPUT SIGNAL	NONE
HORIZONTAL DISPLAY	EXT HORIZ. (X10) ATTEN.
EXTERNAL HORIZ. ATTENUATOR 10-1	CW

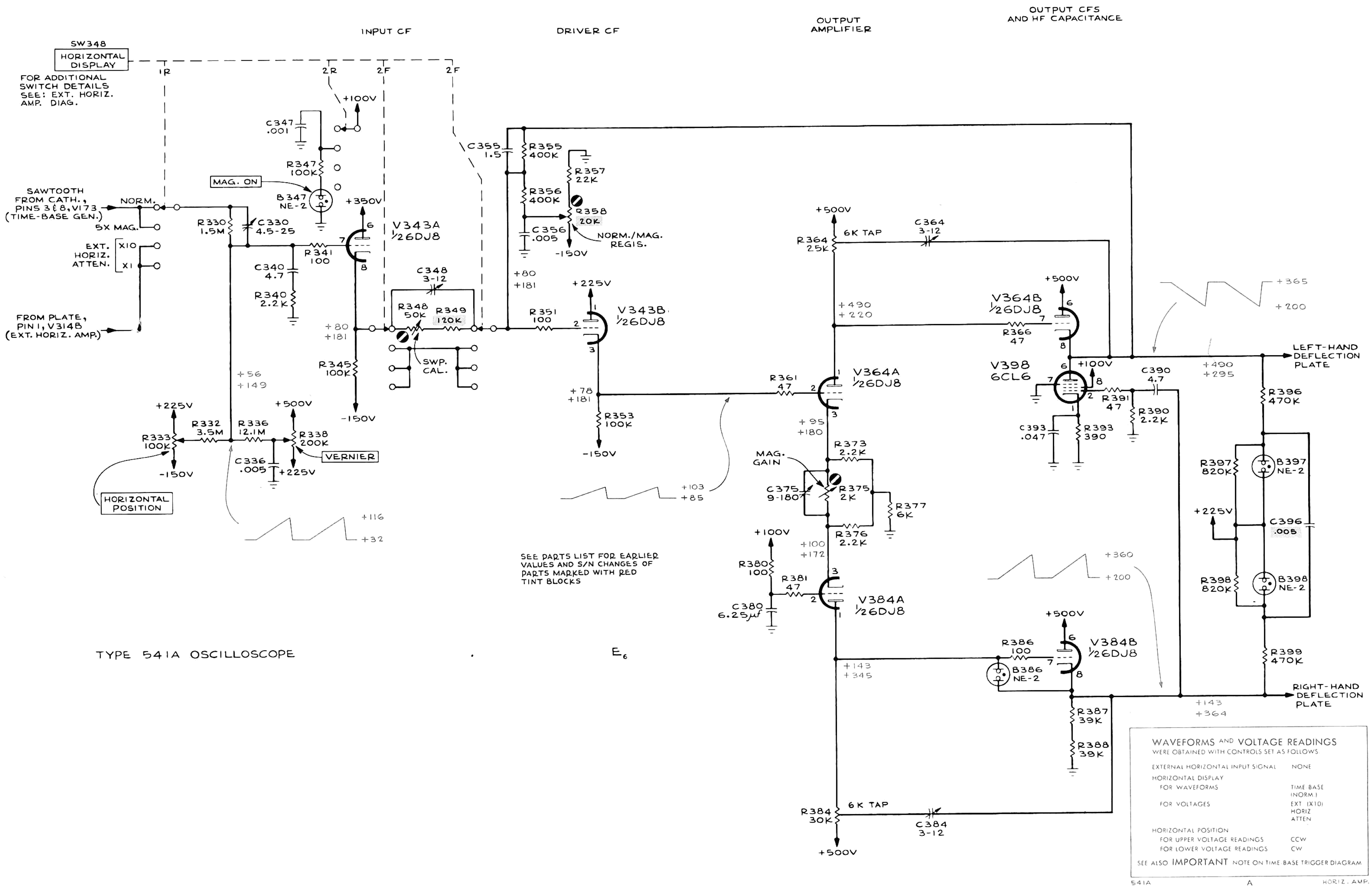
SEE ALSO **IMPORTANT** NOTE ON TIME-BASE TRIGGER DIAGRAM.

541A A EXT. HORIZ.

TYPE 541A OSCILLOSCOPE

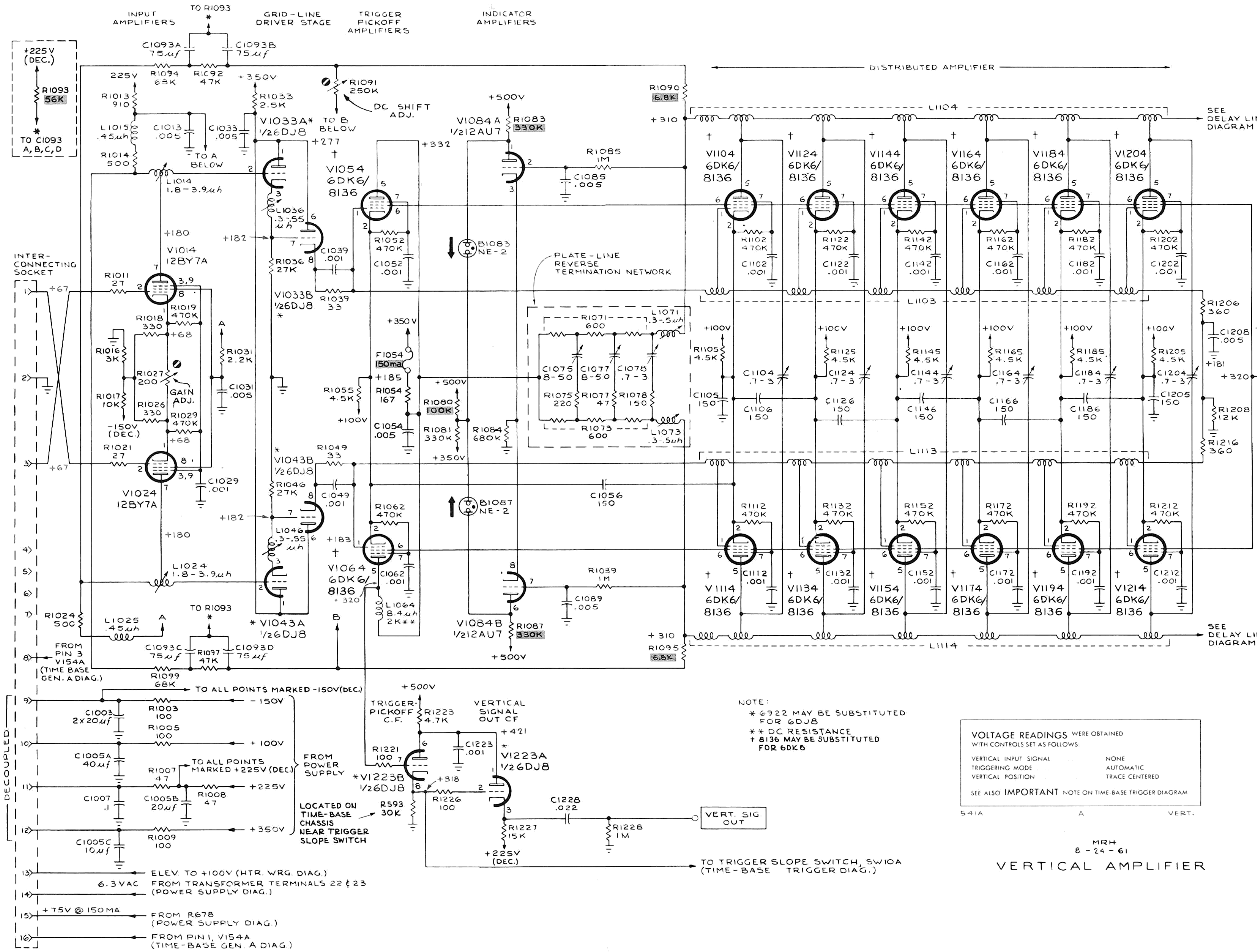
4-21-60
MRH

EXTERNAL HORIZONTAL AMPLIFIER



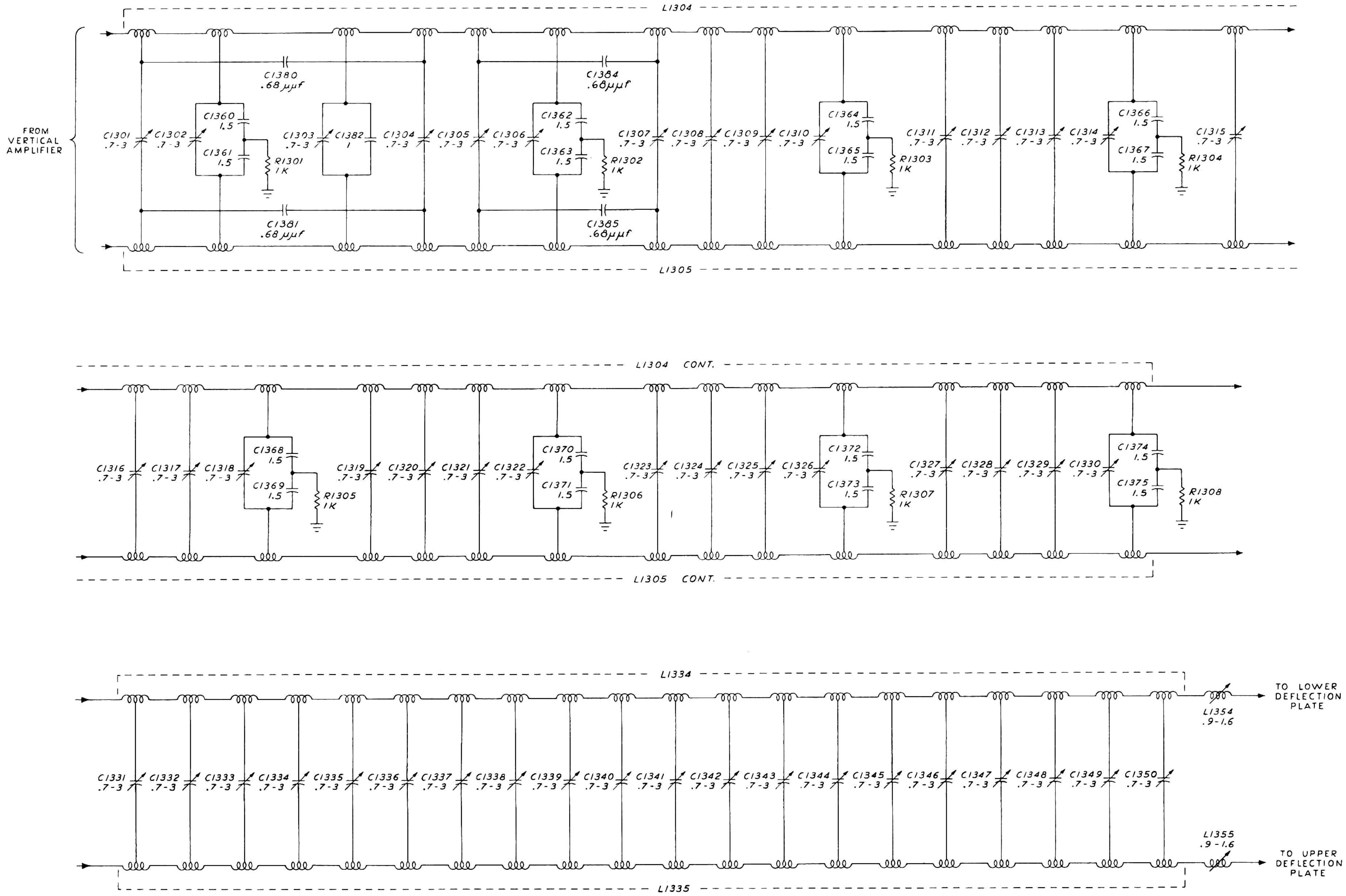
TYPE 541A OSCILLOSCOPE

HORIZONTAL AMPLIFIER



MRH
8-24-61

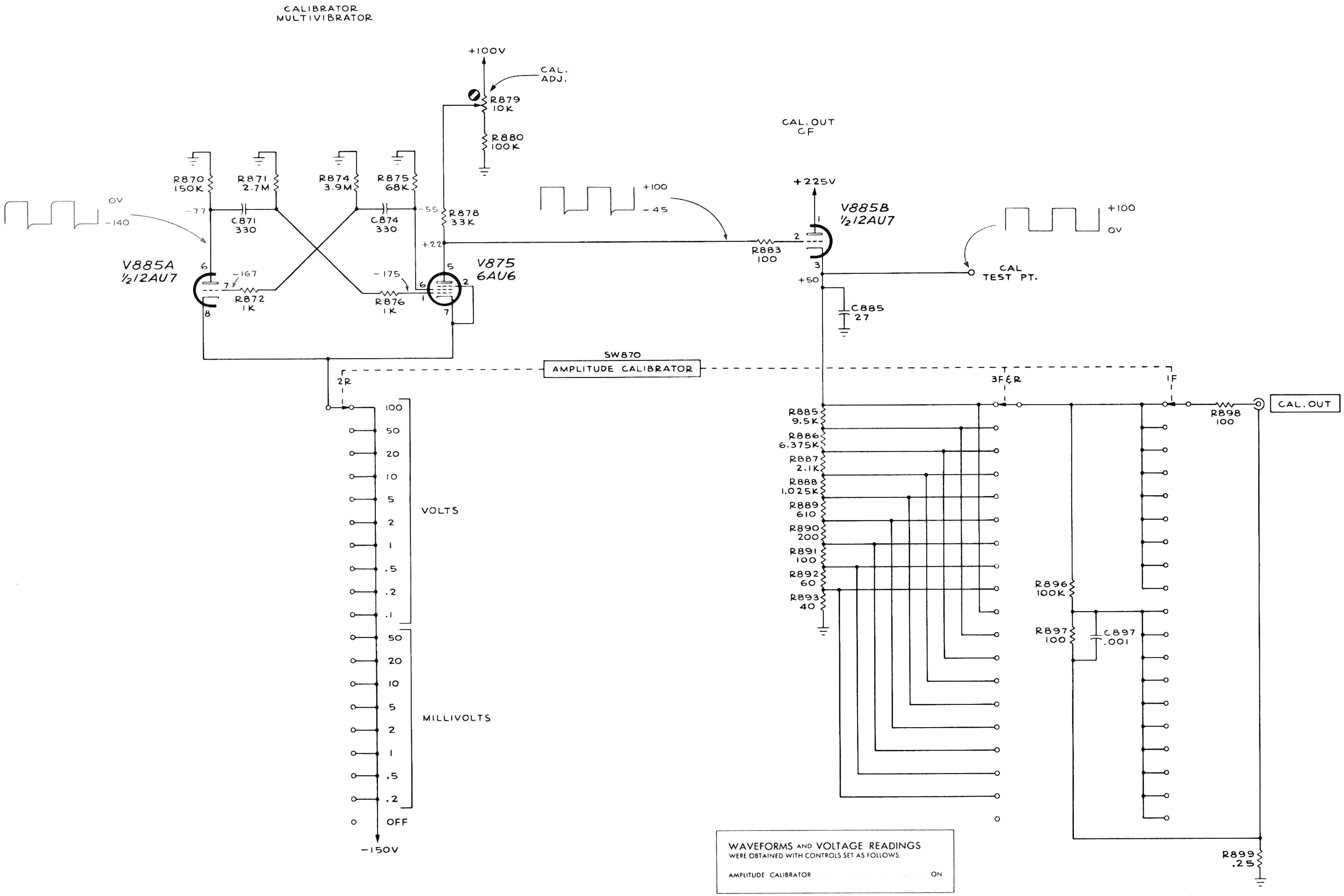
VERTICAL AMPLIFIER



4-2-59 JR

TYPE 541A OSCILLOSCOPE

DELAY LINE NETWORK



541A A CAL.

GAB
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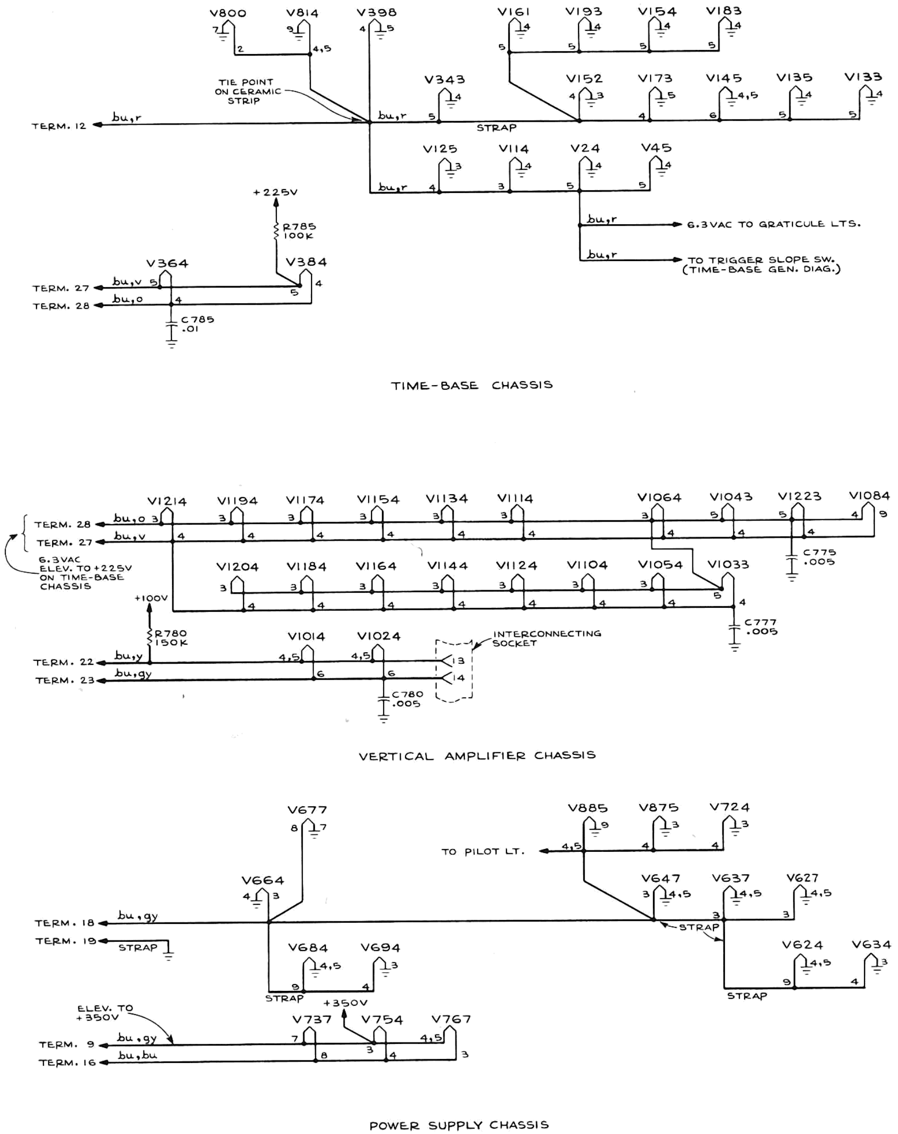
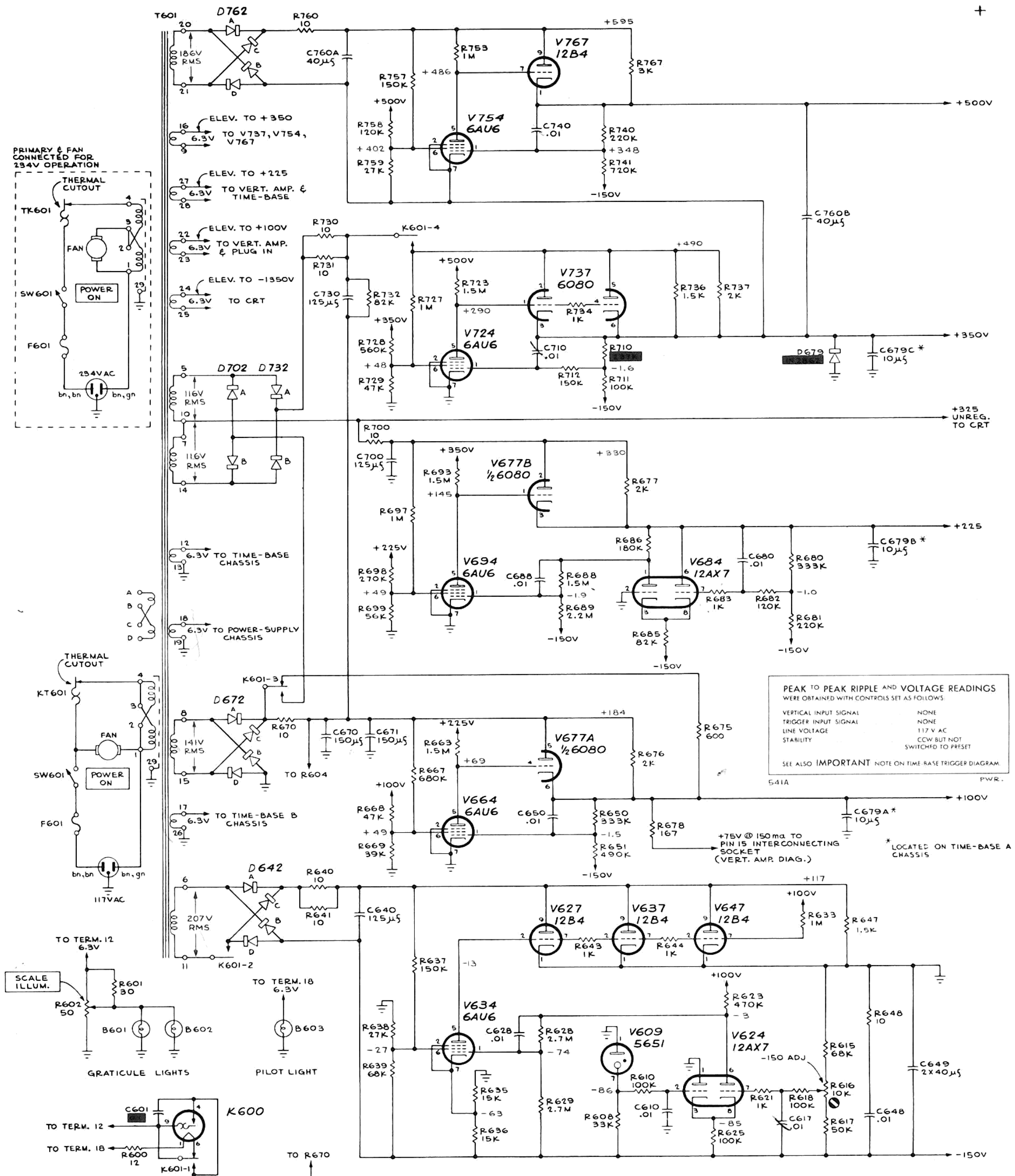
TYPE 541A OSCILLOSCOPE

A 5

CALIBRATOR



HEATER WIRING DIAGRAM



POWER SUPPLY

GAB
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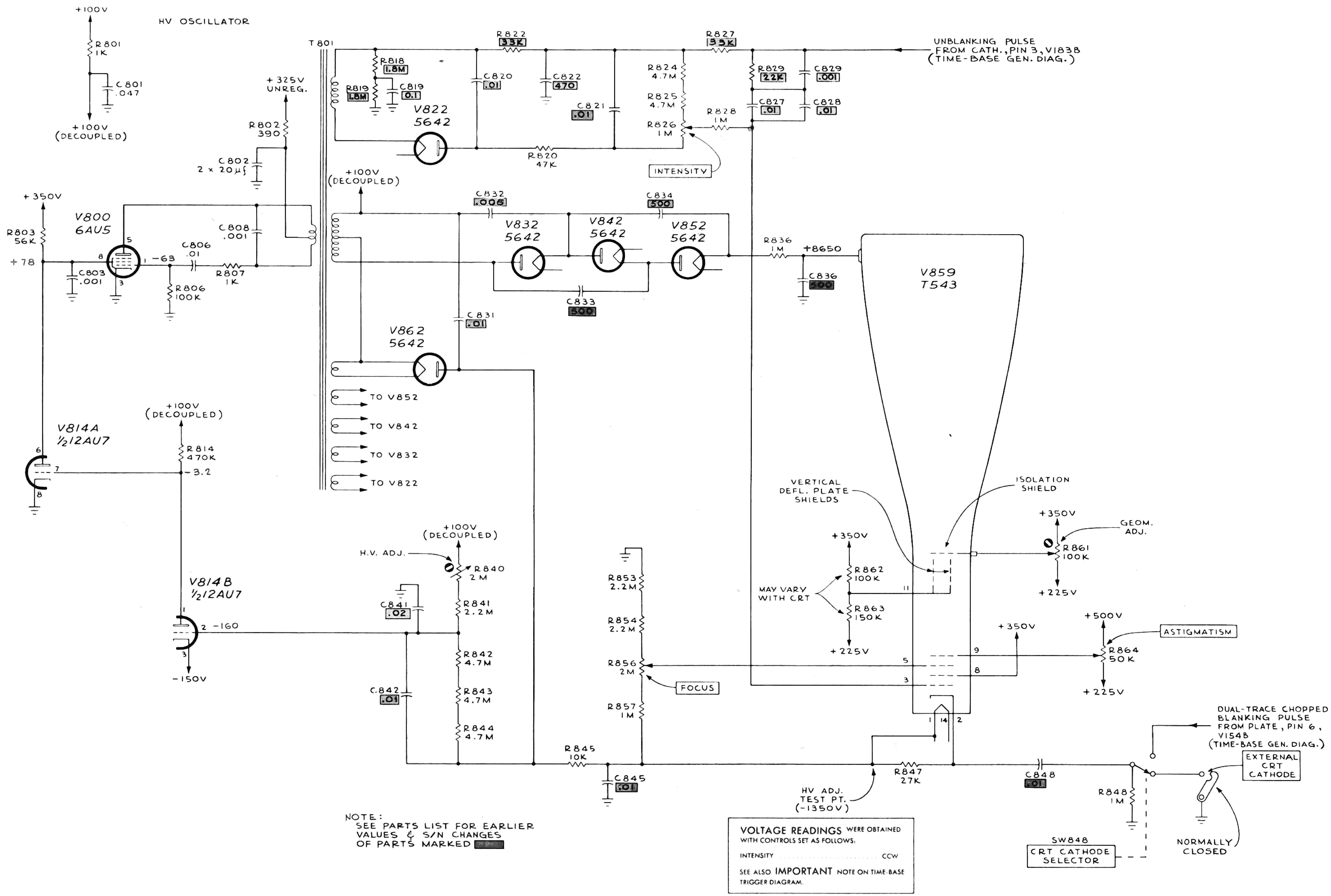

TYPE 541A OSCILLOSCOPE

H1

CRT CIRCUIT

GAB
7-19-61